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EFFECTS OF EXTREMELY HIGH "G" ACCELERATION FORCES ON NASA'S CONTROL AND SPACE EXPOSED TOMATO SEEDS

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U.S. ARMY ARMAMENT RESEARCH, DEVELOPMENT AND ENGINEERING CENTER

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13 ABSTRACT (Maximum 200 words)

An experiment to expose tomato seeds to high levels of mechanical shock after they had spent six years in space aboard NASA's Long Duration Exposure Facility was conducted in the High "G" Air gun Test Facility at Picatinny Arsenal. A group of control seeds which had not been in space were also exposed to high levels of shock. The object of this test was to determine if high levels of gravity affected the growth of the plants grown from this seed or the seeds from these plants. The tomato seeds were exposed from 1,258 times gravity (g) to 119,380 times gravity. Germination occurred at every level of testing and seeds from these plants will be saved to grow plants next year. In general, seeds from the higher shock levels produced higher quality tomatoes, and some abnormalities in developing of green tomatoes were observed at intermediate levels. Genetic effects, if any, are expected to be observed in the next generation which will be grown next year.

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Special thanks are also expressed to John Grant, Edgar K. Stewart, and Mark Eldridge, ARDEC, for their encouragement and support, without which this project could not have been launched.

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INTRODUCTION

In the quest for projects that could support the air gun shock test facility, in anticipation of declining workloads due to the shrinking defense dollar, the Seed Project was conceived as a possible approach to create new business. The origin and proposal to conduct a limited investigation to determine the possible effects of extremely high "g" acceleration on the germination and growth response of tomato plant seeds is indicated in the memorandum dated 20 Nov 1990 (app A).

DISCUSSION

The decision to select tomato seeds for the shock test experiment was influenced by a project that NASA had undertaken. NASA used tomato seeds on board the Long Duration Exposure Facility (LDEF) which was placed in orbit on 7 April 1984 by the space shuttle Challanger and retrieved by the space shuttle Columbia on 12 January 1990. The space exposed experiment developed for students (SEEDS) was a cooperative project of the National Aeronautics and Space Administration (NASA) Educational Affairs Division, NASA Langley Research Center, and the George W. Park Seed Company of Greenwood, South Carolina.* By selecting the same seeds as NASA, it was hoped that a more direct correlation of test results could be achieved.

> "Tomato seeds were selected for LDEF because:
>
> - Their small size permits a large number to be flown
> - They are from a familiar plant
> - Tomato plants are relatively hardy and can be grown throughout the United States.
>
> The particular tomato seed selected was Rutgers California Supreme (Lycopersicon Lycopersicum). Rutgers tomatoes were developed in 1935 at Cook College of Rutgers University by Professor Lyman G. Schermerhorn. Rutgers' tomatoes are a nonhybrid variety that will produce plants with relatively little variation in successive generations. Consequently, changes in plant expression possibly resulting from a high g environment and/or space exposure will be more easily detected.

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*National Aeronautics and Space Administration, "Seeds--Space Exposed Experiment Developed for Students," Teachers' Guide Publication No. Ped-114, dated 1990.

An equal number of tomato seeds from the same seed lot as the flight seeds was placed in storage at the Park Seed Company facilities. The seeds were stored in a controlled environment at 21°C (70°F) and 20% relative humidity for 6 years.

The flight and control seeds were produced by plants subjected only to the natural radiation of their environment. All seeds were produced during the same growing season and were chosen from a seed lot with a high germination rate. The seeds received no chemical treatment."*

Initially, the plans were to plant the seeds in Pro-mix B potting soil only. But then two opportunities came along that were difficult to let pass by. One was inspired by the frequent news reports of the California drought for the past 5 years. What would be the growth response in California desert soil? Inquires were made to the California Department of Agriculture as to where tomatoes were grown, and if they could send a 5-lb sample of that soil. David Estrada, soil scientist of the USDA, Soil Conservation Service of Escondido, California, was contacted and he agreed to send the sample desert soil which is typical of Orange and San Diego counties.

The other opportunity occurred at the 8th Annual North Jersey Regional Science Fair held on 8-9 March 1991 at the Morristown High School in Morristown, NJ which is funded entirely by corporate and private contributions. Although there were many fine exhibits, one which caught my attention was a project entitled, "Growing Tomatoes in Simulated Hawaiian Environment" by Alexandra R. Chutoransky, Grade 11, Immaculata High School, Somerville, NJ. I asked her if she would be interested in growing our shock conditioned tomato seeds in her Hawaiian volcanic soil? She responded positively. When her father, Peter Chutoransky, Chemical Engineer, PhD heard about this, not only he and his daughter, but also Sister Mary Ann Besitka of Immaculata High School expressed an interest in seeing the air gun facility which we willingly obliged. A test report describing their procedures, test results, and observations was prepared and is included in appendix B.

Description of the High "G" Air Gun Test Equipment

The high g air guns, located at Picatinny Arsenal, are designed to simulate field gun firing shocks for the testing of ammunition components such as fuzes, projectile components, explosive elements, propellants, thermal batteries, electronic packages, timing devices, etc. These items are tested under setback forces for structural integrity, functioning, strength, adherence, and deformation.

The two air guns used to conduct the mechanical shock tests on the tomato seeds were the 2 inch and 5 inch smooth bore guns. The 5 inch air gun was used for the lower levels of shock, and the 2 inch air gun was used to attain higher levels of shock. Both guns use high pressure air instead of propellant powder to accelerate the test item.

The guns consist of a breech section where the piston (or projectile) containing the test item is inserted (fig. 1) and long barrel extensions, closed on the muzzle end, provide an air cushion which decelerates the piston once it is fired. A 50-horsepower, six-stage air compressor, connected to a booster compressor, is capable of producing pressures to 30,000 psi to supply the breech. The aluminum piston is assembled with an aluminum rupture diaphragm on the rear end and secured with a large nut. The diaphragm has a circular groove machined on one side which controls the rupture pressure and thereby controls the acceleration level. The highest level of acceleration is reached by using the lightest piston assembly at the maximum rupture pressure. The variety of pistons used to attain increasing levels of acceleration is shown in figure 2. The maximum g level was achieved by using a 2-inch piston with a diaphragm that was machined as an integral part of the piston in order to obtain the lightest weight. An exploded view of the 2-inch piston prior to assembly into the 5-inch piston is shown in figure 3. A view of a typical individual 5-inch and 2-inch piston assembly with the diaphragm ruptured from the respective piston (also shown with an unruptured diaphragm alongside) is illustrated in figure 4. A disassembled view of two types of 2-inch pistons with the foam rubber cushions is shown in figure 5. A more detailed description of the air gun facility is given in appendix C.

Test Procedure

Two groups of seeds were subjected to increasing levels of acceleration: the "control seeds" with test results recorded in tables 1 and 2 and the "space exposed seeds" with test results recorded in tables 3 and 4. A group of seeds were placed in the bottom of the piston cavity (fig. 6), insuring that none of the seeds were in contact with each other. A piece of foam rubber was placed against the seeds to prevent them from moving about during assembly of the piston and to provide a soft cushion against the clamping action of the aluminum screw fixture. The 2-inch piston (fig. 7) was placed inside the 5-inch piston (fig. 8) for a series of low g tests using the 5-inch air gun. A diaphragm was selected to rupture at a predetermined pressure corresponding to the g level desired. The whole piston assembly was then inserted into the breech of the gun (figs. 9 through 12). Operating from the air gun control panel (fig. 13), the compressor was started and permitted to pump until the diaphragm ruptured. The sudden release of the restrained piston produced the mechanical shock experienced

by the seeds. The maximum acceleration level produced was 119,380 g's as recorded in table 1. From table 5, it is noted that the average weight of a tomato seed is 2.762 mg. Therefore, in effect , 2.762 mg is equivalent to a force of 330 grams (0.73 lb) at the highest g level tested.

Upon retrieval of the piston from the breech, the cap was unscrewed from the piston and the seeds removed (fig. 14) and examined under a stereomicroscope (fig. 15).

The individual seeds were then planted in the cell pack (fig. 16) and watered daily or as needed (fig. 17), identified with a horticulture marker (fig. 18), and covered with a plastic bag to maintain a humid and constant environment (fig. 19).

After the tomatoes have fully grown, the seeds were removed and stored for future planting as follows:

1. Use a wooden cutting board
2. Use paper towel roll folded into six panels
3. Cut off one side of tomato from top to bottom to expose the seeds
4. Remove 1/4 to 1/3 of the seeds available from the whole tomato
5. Scrape the seeds off the cutting board onto the paper towel; do not remove the wet flesh from the seeds
6. Spread the seeds out along a line on the paper towel
7. Mark the plastic horticulture marker with the appropriate information (e.g., experiment number) and place on towel along side the seeds
8. Roll up towel starting from one end; secure each end with a wire tie
9. Wash cutting board and knife after each operation to prevent the seeds from becoming mixed with seeds from the previous operation

11. Mark paper towel on outside of each roll for identification (e.g., experiment number)
12. Wrap paper towel roll with aluminum foil
13. Store the seeds in a dry secured area, free from insects and rodents

Test Results

16 April 1991 (table 1)

Out of the 12 control seeds tested at each g level in the air gun, six were planted immediately after the test. The other six were divided into two groups of three each which were reserved for future planting experiments in California desert soil and Hawaiian volcanic soil.

On 15 April 1991, the following test results were reported:

- The control group of seeds were the last ones to germinate. However, after 2 days, all that germinated were at the same height.

- The first to germinate was experiment 6, next experiment 4, next experiment 9.

- Three out of six cells from each cell pack germinated in the early stages with the exception of experiment 8.

- Experiment 11: Of the three plants that came up, only one seed was not chipped. The other two had a portion of the edge broken off from the high g test. Of those two, one had only one primary leaf instead of the usual two. Of the three that have yet to germinate, all three were chipped.

- Experiment 6: Germination occurred on 13 April 1991 at approximately 0730 hours.

- All experiments germinated by 2100 hours 14 April 1991.

16 May and 18 May 1991 (table 2)

The growth of the seedlings generally proceeded normally (fig. 20). However, in experiments 4 and 8, an unusual event occurred--a dwarf plant appeared (fig. 21). What the significance of this phenomenon could mean will be left to the scrutiny of horticulturists. One possible suggestion is given in the following paragraph on grass seed experiments. The development and progress of the NASA control seed tomato plants (figs. 22 through 28) is self explanatory. On 26 May 1991, all the seedlings growing under the artificial light, except the 11 plants (one from each g-level) given to Alexandra Chutoransky, were transplanted to a garden in Pennsylvania to avoid damage from the deer population at Picatinny Arsenal. The seedlings were treated with 5 oz of "Glacial Rock Dust" and a handful of "Tomatoes Alive" which

contains microbes to feed the plant roots. No chemical fertilizer was used. The area where the tomato seedlings were planted had been in permanent sod for 44 years.

Comment on Grass Seed Experiment

The dwarf plant (fig. 21), which has never been observed before in 30 yr of experience with tomato plants, suggested the possibility of producing a dwarf grass plant. It was decided to shock test six grass seeds (Rebel II) at the same g level range that the dwarfs appeared: 19,467 and 38,596 g as indicated in table 2. The test results, however, did not produce dwarf grass plants. In fact, five out of six seeds germinated on time from both g-levels, and they grew normally. Although the potential for dwarf grass still exists, it was decided to discontinue any further air gun testing at this time.

NASA Control Seeds Mechanical Shock Test

- No mutations were observed on the first generation.

- Germination was very late, up to 1 month after seeds were supposed to have germinated. This was observed in five plants out of a total of 72 plants that germinated.

- Tomato shape was uniform, coloration was normal and taste was typical for the Rutgers California Supreme (Lycopersicon Lycopersicum) tomatoes.

- Growth pattern appeared normal.

- Seeds appeared normal.

- Height of the tomato plants and the size of the tomatoes were less than normal (slightly smaller). However, this was expected because of the prolonged drought from May through September 1991. Pennsylvania, Monroe County, where the plants were grown, had 6 inch less rainfall from the yearly average. This drought condition affected all crops in northeastern Pennsylvania. (Note: Since no water faucet was available at the tomato garden site, irrigation was not feasible. Consequently, water was delivered to the garden in 55-gallon drums on board a pickup truck and using a hose to siphon the water from the drum to direct it at the base of the plants.)

30 August 1991 (table 4)

- Out of the 12 seeds that were planted in Pro-Mix B soil, only five germinated.

- Out of the 12 seeds that were planted in California desert soil, only five germinated.

- Normal germination takes 7 to 14 days. These took 2 weeks longer to germinate or approximately 28 days.

- The others that did not germinate were watered daily and sprayed with liquefied sea weed (liquid kelp). However, if these seeds fail to germinate, the possible causes could be due to shock damage, insect (eaten), dried out, fungus, or disease.

- For comparison, the germination rate reported from 100 elementary schools, 100 high schools, and 100 colleges across the United States ran an overall average of 70.3% for the control seeds and 73.8% for the space exposed (flight) seeds.

CONCLUSIONS

NASA Control Seeds

The percentage of germination (table 2) was higher than 50% at all g-levels.

The germination rate of the shock-conditioned seeds equaled or exceeded the control group response. The extreme form of gravity had little or no effect on the germination rate. Considering the fact that the seeds were 6 years old, it would be expected that the germination rate would be lower for both the control and shock conditioned seeds.

NASA Space Exposed Seeds

At this point in time, 30 September 1991, the tomatoes are in the process of flowering, and all growth appears normal. No mutations were observed.

Chutoransky's Report

Surprising and significant results were obtained from their experiments as stated in the summary of the report (app B): "While the abnormal tomato ripening should be of research interest, the improved quality characteristics of the high-g tomatoes could be of some commercial significance. Each deserves more extensive and quantitative investigation."

RECOMMENDATIONS

It is recommended that other environmental tests on seeds be considered, e.g., high frequency mechanical vibration under ambient or combined with temperature conditioning; sustained levels of acceleration for long periods of time in a centrifuge (to 60,000 g) which is available at the Harry Diamond Laboratories, a U.S. Army Research Laboratory in Adelphi, MD, located conveniently next to the U.S. Department of Agriculture Main Research Center in Beltsville, MD; or placing specimen seeds in a pressure vessel and subjecting them to increasing levels of gas pressure. As far as can be determined from inquiries to NASA, U.S. Department of Agriculture, and a commercial seed company, no one has ever performed such tests before.

Table 1. NASA control seeds mechanical shock test--
preliminary test results as of 16 April 1991

Shock test date	Experiment	Acceleration level[a] (g)	Cells planted[b]	Cells germinating
4/8/91	Control	1	6	3
4/8/91	1	1,258	6	3
4/8/91	2	4,195	6	3
4/8/91	3	11,440	6	5
4/8/91	4	19,468	6	3
4/8/91	5	30,730	6	3
4/8/91	6	52,286	6	2
4/8/91	7	58,438	6	4
4/8/91	8	38,569	6	1
4/8/91	9	98,045	6	4
4/8/91	10	98,275	6	4
4/8/91	11	119,380	6	3

Preliminary Observations:

a. Germinations are proceeding normally.

b. Germination rate at 119,380 g is the same as the control group.

Remarks: Considering the fact that seeds have survived a shock of 119,380 g, this accomplishment could spark interest in the botanical field to consider using the air gun test facility for other research test programs.

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[a] Acceleration levels of 200,000 g were achievable if certain parts were available.
[b] Only one seed per cell was planted.

Table 2. NASA control seeds mechanical shock test results as of 16 May and 18 May 1991. Potting soil type: Pro-Mix B[a]

Shock test	Experiment	Acceleration (g)	Cell pack	Plant	Growth height (cm) 16 May	Remark	Growth height (cm) 18 May	Remark
4/8/91	Control	1	1	1	b		19.0	
				2	b		26.0	
				3	6.0		c	
				4	d		d	
				5	d		d	
				6	d		d	
4/8/91	1	1,258	2	1	b		27.5	
				2	b		24.0	
				3	19.0		c	
				4	2.5	Newly emerged	c	
				5	d		d	
				6	d		d	
4/8/91	2	4,195	3	1	20.0		c	
				2	b		29.5	
				3	b		21.0	
				4	d		d	
				5	d		d	
				6	d		d	
4/8/91	3	11,440	4	1	b		28.0	
				2	b		28.5	
				3	13.5		c	
				4	24.5		c	
				5	20.5		c	
				6	21.0		c	
4/8/91	4	19,468	5	1	b		29.5	
				2	b		25.0	
				3	19.5		c	
				4	18.0		c	
				5	3.0	Dwarf	c	
				6	d		d	

Table 2. (cont)

Shock test	Experiment	Acceleration (g)	Cell pack	Plant	Growth height (cm) 16 May	Remark	Growth height (cm) 18 May	Remark
4/8/91	5	30,730	6	1	b		28.0	
				2	18.0		c	
				3	16.0		c	
				4	20.0		c	
				5	d		d	
				6	d		d	
4/8/91	6	52,286	7	1	b		26.0	
				2	19.5		c	
				3	18.5		c	
				4	d		d	
				5	d		d	
				6	d		d	
4/8/91	7	58,438	8	1	b		30.0	
				2	b		27.5	
				3	9.5		c	
				4	19.5		c	
				5	14.5		c	
				6	d		d	
4/8/91	8	38,596	9	1	b		18.5	
				2	b		23.0	Cracked
				3	13.0		c	
				4	3.5	Dwarf	c	
				5	d		d	
				6	d		d	
4/8/91	9	98,045	10	1	b		24.0	
				2	b		29.5	
				3	14.5		c	
				4	15.0		c	
				5	d		d	
				6	d		d	

Table 2. (cont)

Shock test	Experiment	Acceleration (g)	Cell pack	Plant	Growth height (cm) 16 May	Remark	Growth height (cm) 18 May	Remark
4/8/91	10	98,275	11	1	b		27.0	
				2	13.5	Chipped	c	
				3	16.0	Chipped	c	
				4	16.0		c	
				5	d		d	
				6	d		d	
4/8/91	11	119,380	12	1	b		21.0	
				2	b		24.0	
				3	16.5	Chipped	c	
				4	d		d	
				5	d		d	
				6	d		d	

[a] Pro-Mix B soil does not contain any soil. It is a synthetic growing medium available from a commercial supplier.

[b] Seedling transplanted from cell pack to paper cups on 13 May 9l and transplanted to garden on 26 May 91.

[c] Height measurement of seedling taken when transplanted.

[d] Seed did not germinate.

Table 3. NASA space exposed seeds mechanical shock test, 24 June 1991

Experiment	Acceleration (g)	NASA canister	NASA layer	Seeds tested	Seeds planted Pro-Mix B soil	Seeds planted California desert soil	Seeds reserved Hawaiian volcanic soil	Seeds reserved for future use
Control*	--	--	--	--	--	--	--	--
1	12,348	5	A	12	3	3	3	3
2	23,620	5	D	12	3	3	3	3
3	115,997	5	B	12	3	3	3	3
4	44,880	5	C	12	3	3	3	3

* The NASA space exposed control seeds were not planted because the test results are available from the many participants in the NASA program.

Table 4. NASA space exposed seeds mechanical shock test, test results as of 30 August 1991

Date seed planted	Experiment	Acceleration (g)	Cell pack	Plant	Pro-Mix B soil: Germination date	Pro-Mix B soil: Growth height (cm) 9/3/91	California desert soil: Germination date	California desert soil: Growth height (cm) 9/3/91
a	Control	--	--	--	--	--	c	--
6/24/91	1	12,348	1	1	6/30/91	31.5	6/30/91	34.5
				2	--	b	6/30/91	33.5
				3	--	b	--	b
6/24/91	2	23,620	2	1	6/30/91	36.0	6/30/91	34 5
				2	6/30/91	35.0	--	b
				3	6/30/91	32.5	--	b
6/24/91	3	115,997	3	1	7/21/91	b	7/21/91	9.5
				2	--	b	--	b
				3	--	b	--	b
6/24/91	4	44,880	4	1	6/30/91	35.0	7/21/91	9.5
				2	--	b	--	b
				3	--	b	--	b

[a] The NASA space exposed control seeds were not planted because the test results were available from the many participants in the NASA program.

[b] Seed did not germinate.

[c] The California desert soil compacted much more readily than the Pro-Mix B potting soil. As a consequence, the roots encountered more difficulty in penetrating the soil. The compacted soil, which was deprived of humus and other organic matter, also had little or no air space (oxygen) for the roots to breathe. Therefore, it was to be expected that the roots in the Pro-Mix B soil were much more elaborate.

Table 5. Tomato seed weight and size chart

NASA (control) earth-based seed tomato Rutgers California Supreme

Seeds	Weight (mg)	Length (mm)	Width (mm)	Thickness (mm)	Thickness (in.)
		Dimensions			
10 avg	2.710	3.1	2.1	0.584	0.023
10 avg	2.470	2.9	2.5	0.559	0.022
10 avg	3.615	3.0	2.1	0.533	0.021
10 avg	2.596	3.0	2.6	0.457	0.018
10 avg	2.421	3.0	2.5	0.508	0.020
		3.2	2.3	0.559	0.022
Average	2.762	3.3	2.6	0.584	0.023
Std dev	0.490	2.9	1.8	0.559	0.022
		3.1	2.2	0.584	0.023
		2.9	2.2	0.610	0.024
		2.9	2.0	0.660	0.026
		2.9	2.1	0.483	0.019
		3.2	2.3	0.533	0.021
		3.0	2.8	0.635	0.025
		3.1	2.5	0.533	0.021
		2.7	2.2	0.533	0.021
		2.9	2.7	0.610	0.024
		3.2	2.4	0.483	0.019
		2.3	1.9	0.533	0.021
		2.8	2.2	0.381	0.015
	Avg	3.0	2.3	0.546	0.022
	Std dev	0.2	0.3	0.065	0.003

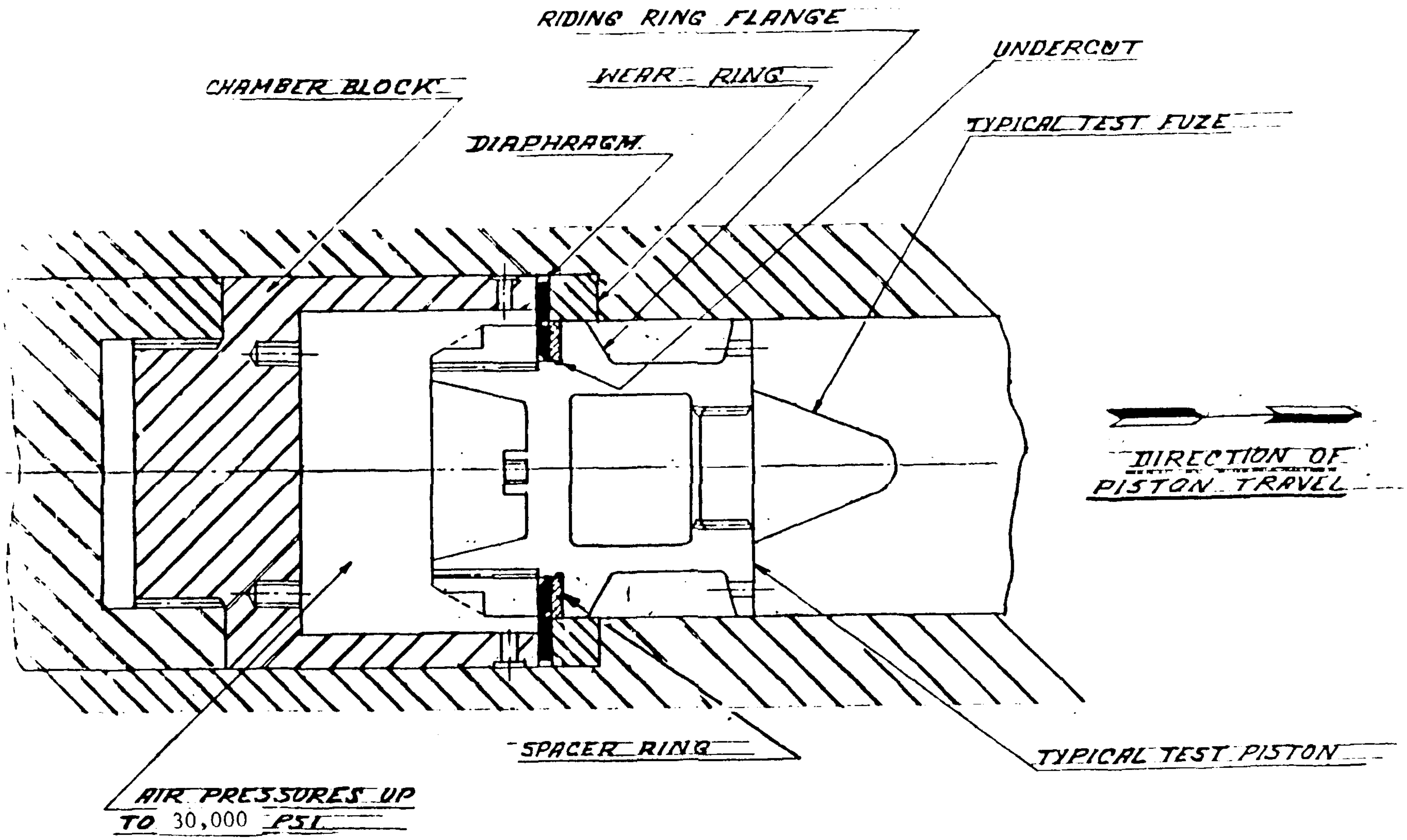


Figure 1. Air gun assembly

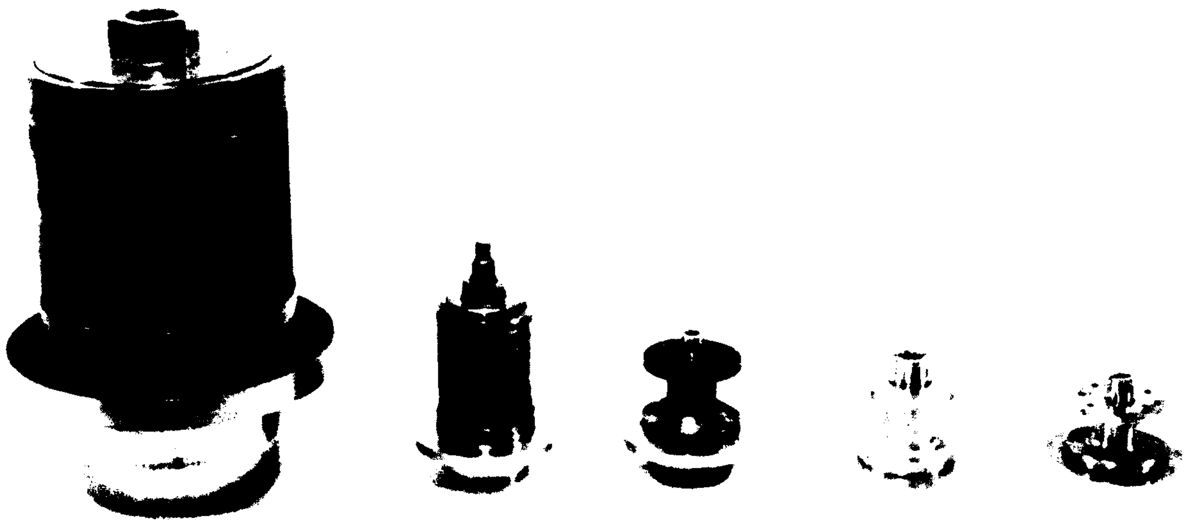


Figure 2. Variety of pistons used for seed test

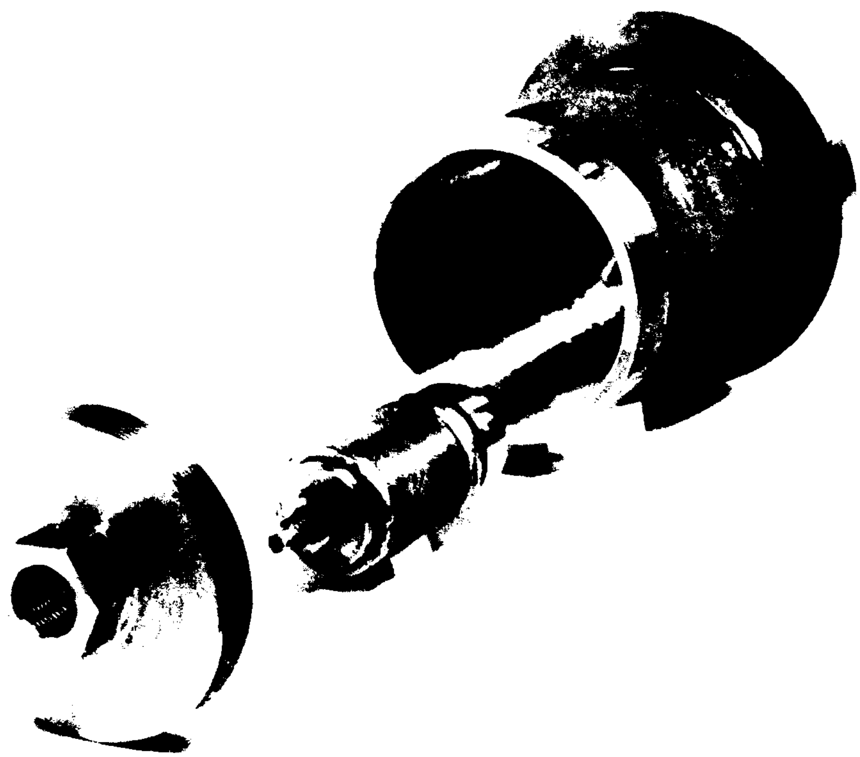


Figure 3. 2-inch piston prior to assembly into 5-inch piston

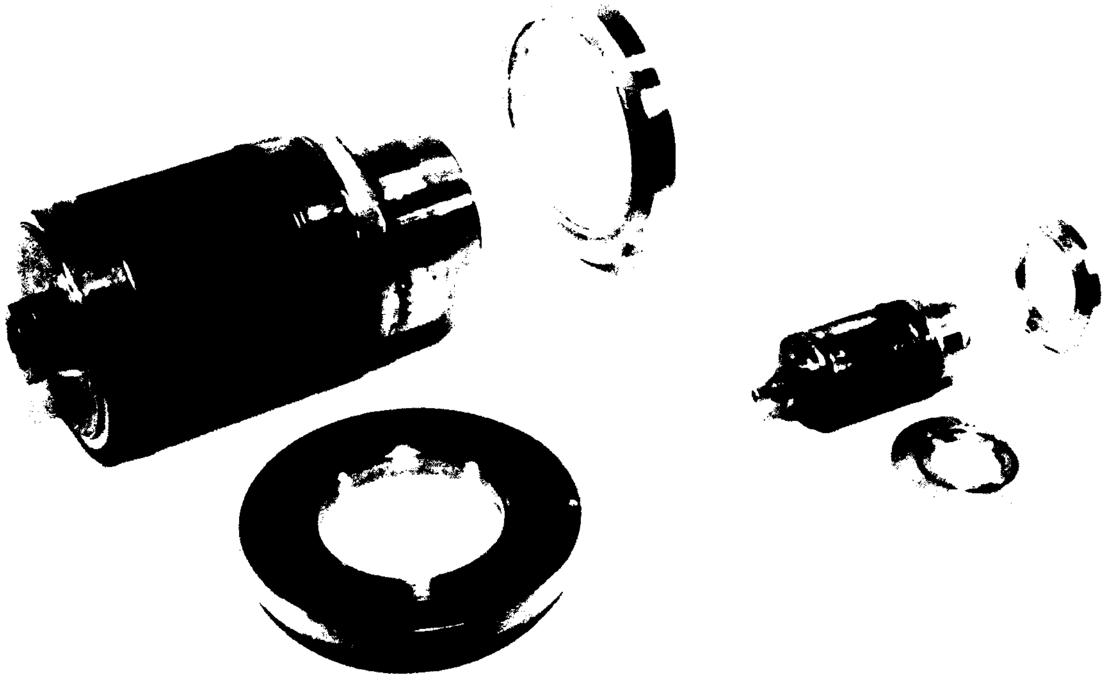


Figure 4. 5-inch and 2-inch pistons with ruptured and unruptured diaphragms

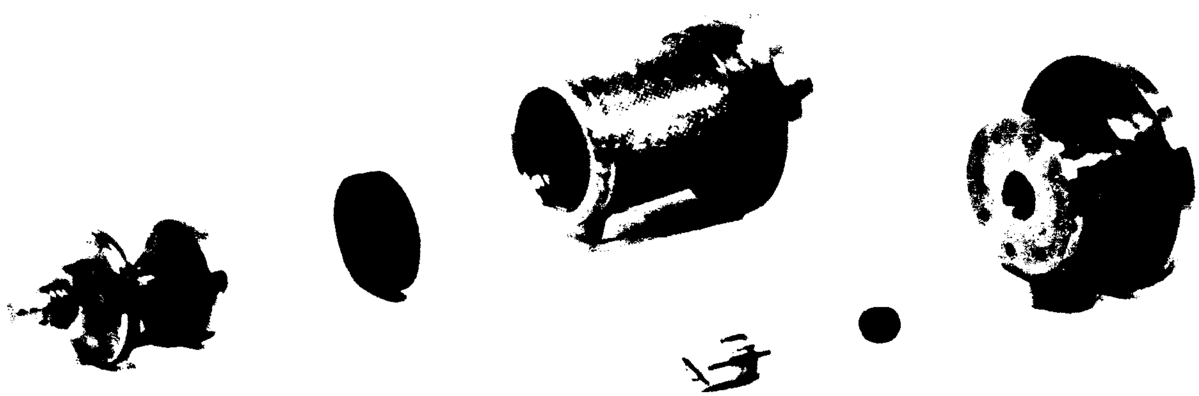


Figure 5. Two types of 2-inch pistons with foam rubber cushions

Figure 6. Inserting seeds into 2-inch piston

Figure 7. Assembling 2-inch piston

Figure 8. Assembling 2-inch piston into 5-inch piston

Figure 9. Inserting piston into 5-inch air gun

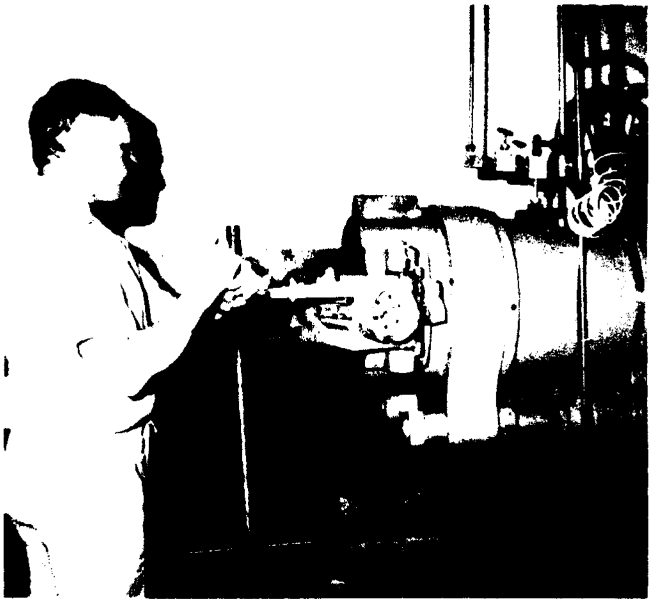


Figure 10. Closing breech of 5-inch air gun

Figu... Inserting piston into breech

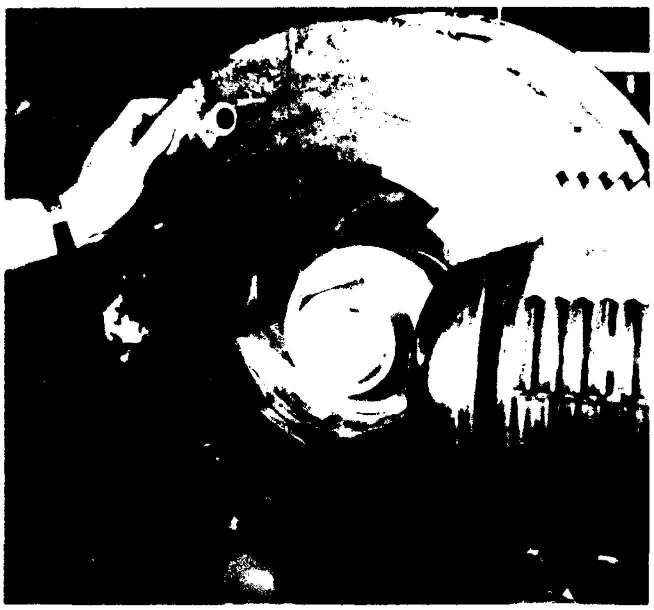


Figure 12. Partial insertion of piston into breech

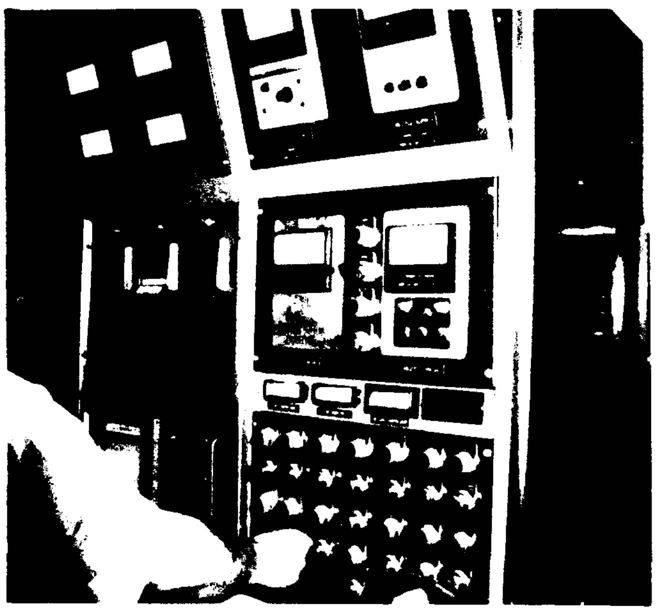


Figure 13. Control panel for air guns

Figure 14. Removing seed from 2-inch piston

Figure 15. Stereo microscope examination of seed

Figure 16. Planting seed into potting soil after shock test

Figure 17. Water application to potting soil

Figure 18. Cell pack with horticulture marker

Figure 19. Cell pack covered with plastic to maintain moisture

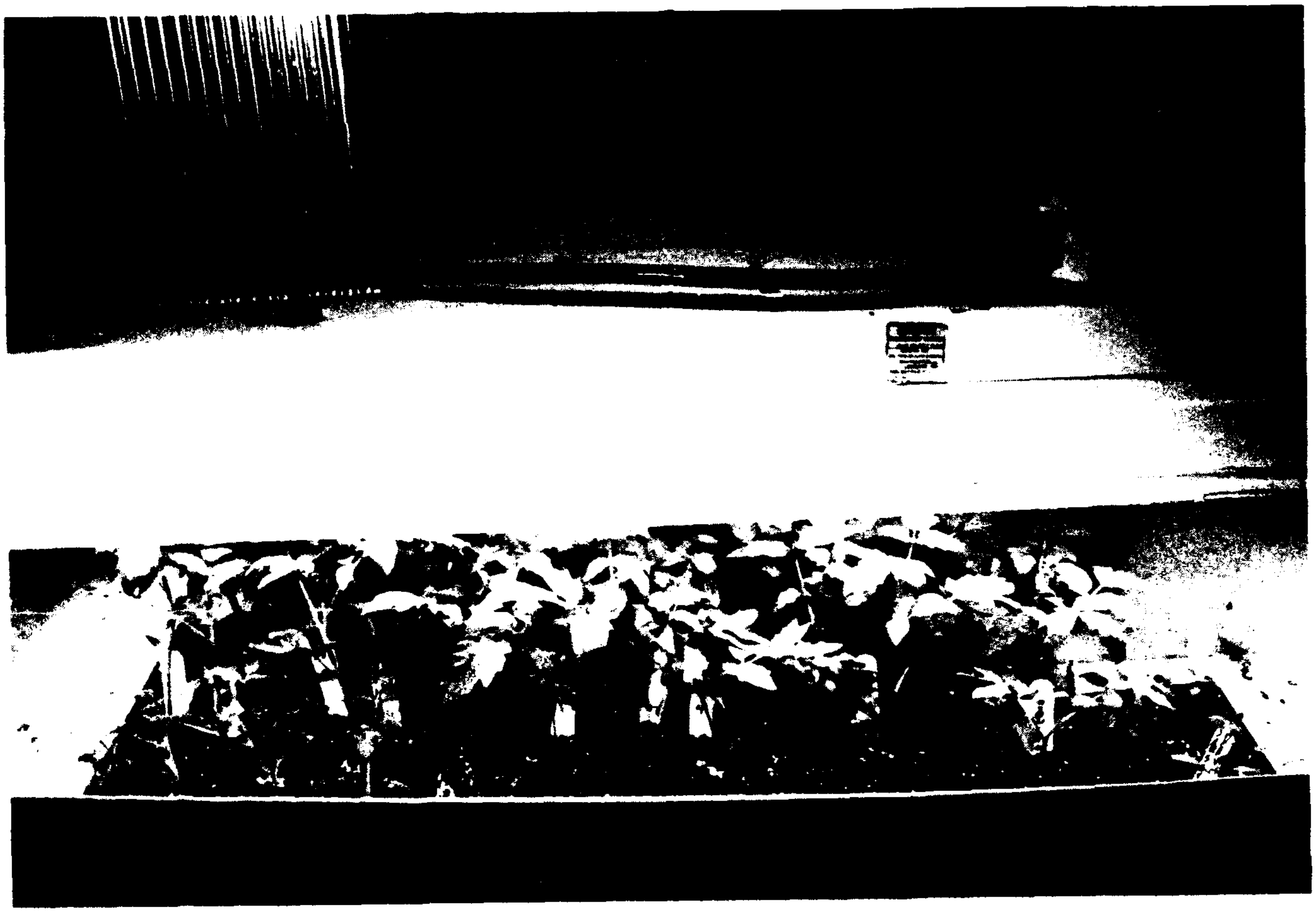


Figure 20. NASA control seeds mechanical shock test,
experiments 1 through 11 as of 9 May 1991

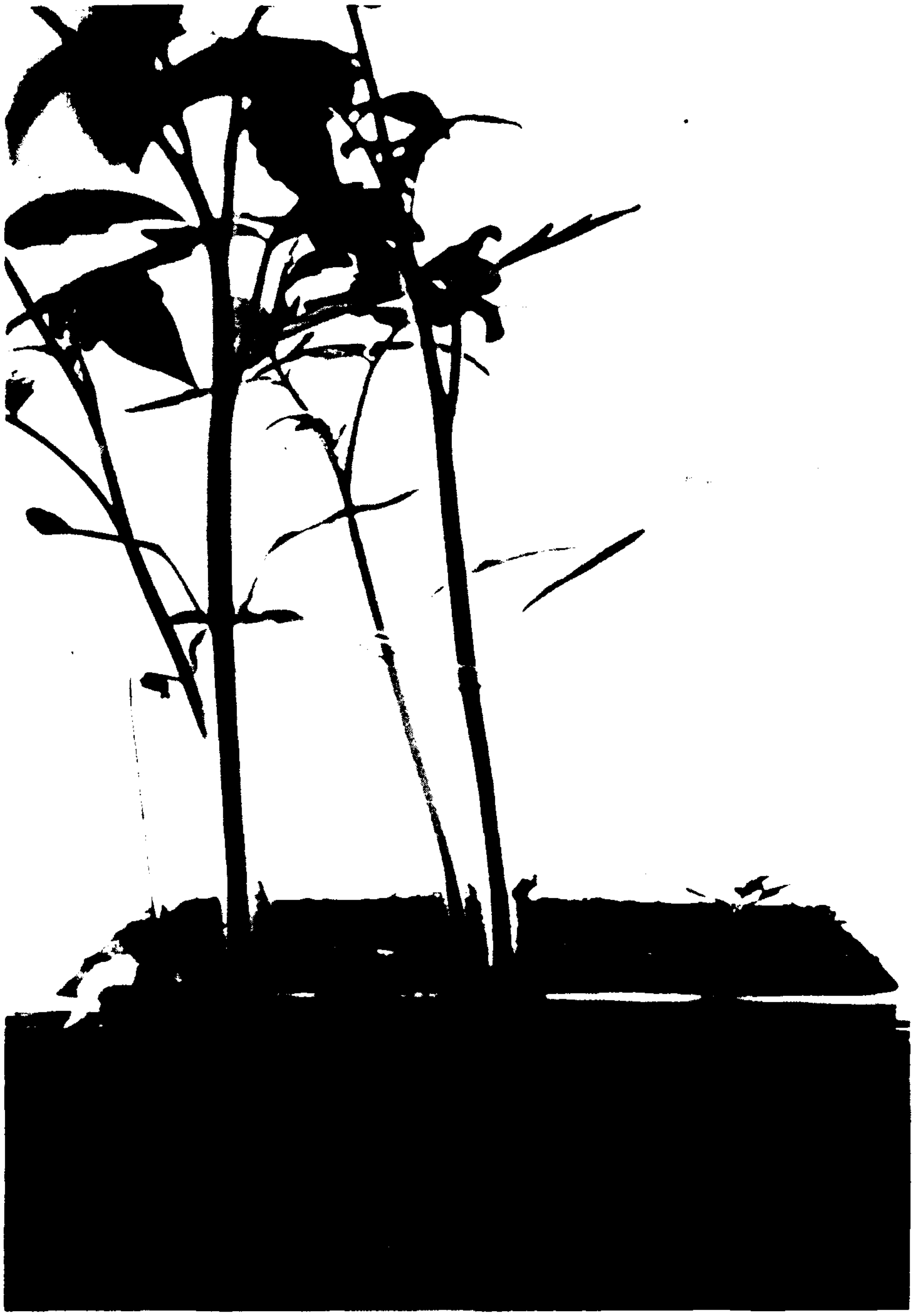


Figure 21. NASA control seeds mechanical shock test,
experiment 4 as of 9 May 91 (note the dwarf plant)

Figure 22. NASA control seed mechanical shock test; tomato seedlings in cell pack under light with timer for first 5 weeks

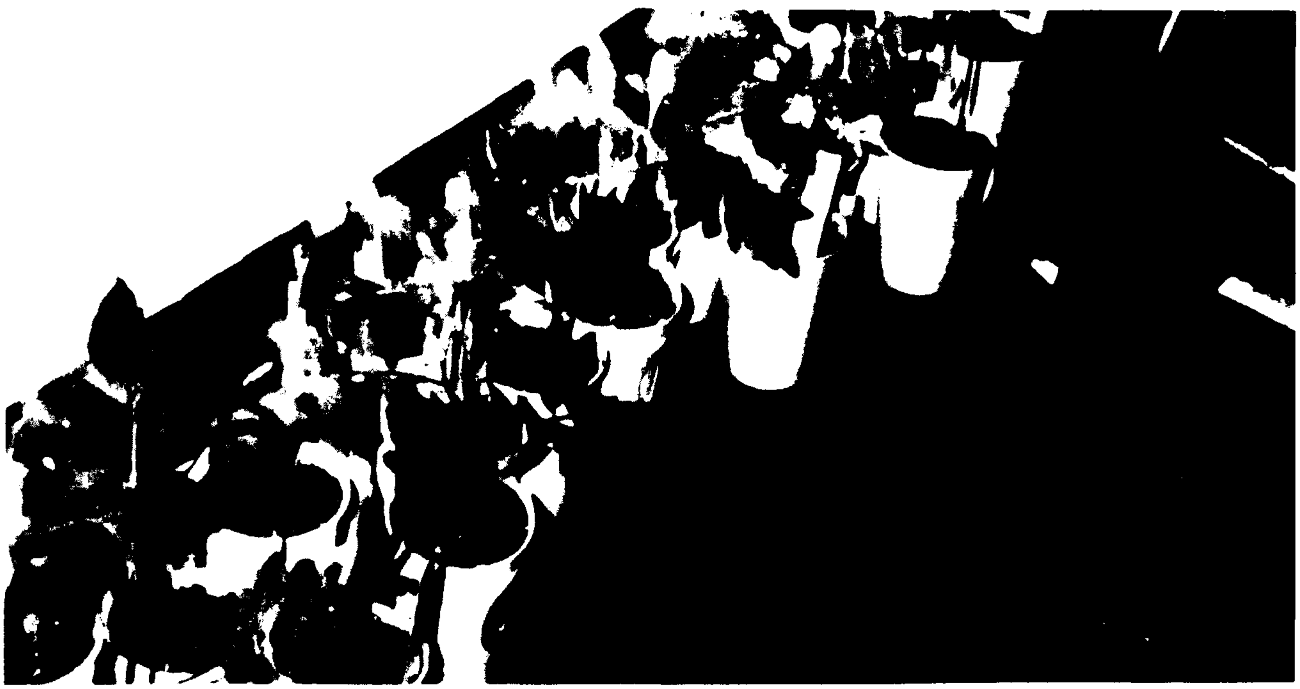


Figure 23. NASA control seed mechanical shock test; tomato seedlings growing; light with timer set for 14 hours after being transplanted from cell pack

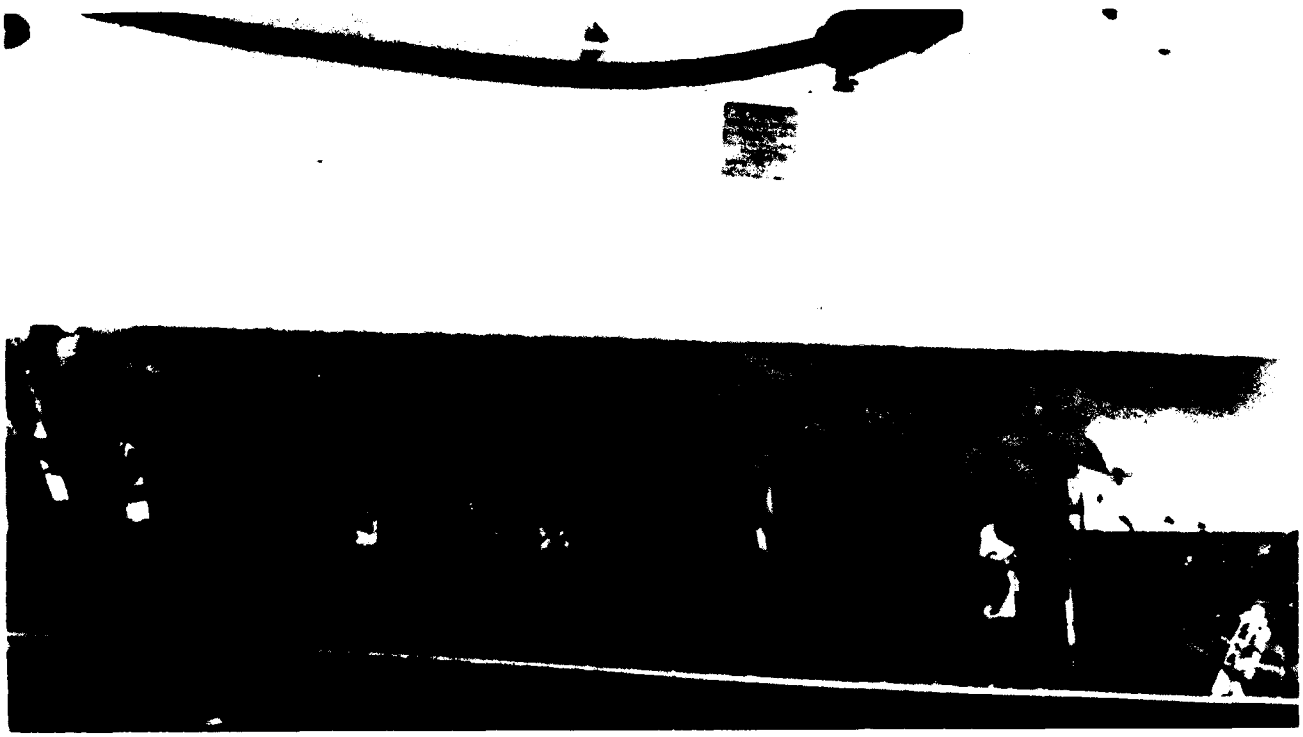


Figure 24. NASA control seed mechanical shock test; close-up of tomato plants under the light

Figure 25. NASA control seed mechanical shock test; tomato seedlings exposed to first day of sun light and about to be transplanted to paper coffee cups

Figure 26. NASA control seed mechanical shock test; tomato plants transplanted to garden

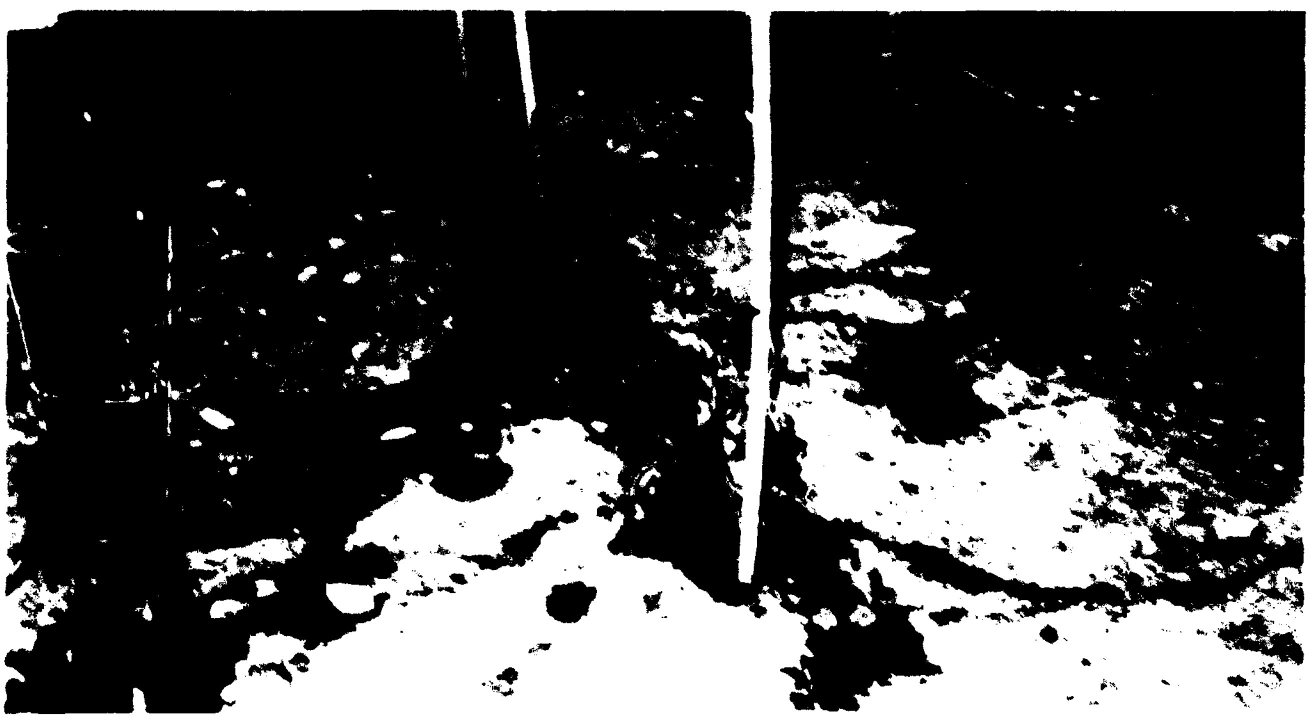


Figure 27. NASA control seed mechanical shock test; tomatoes staked and interplanted with dwarf marigolds for nematode protection of tomatoes

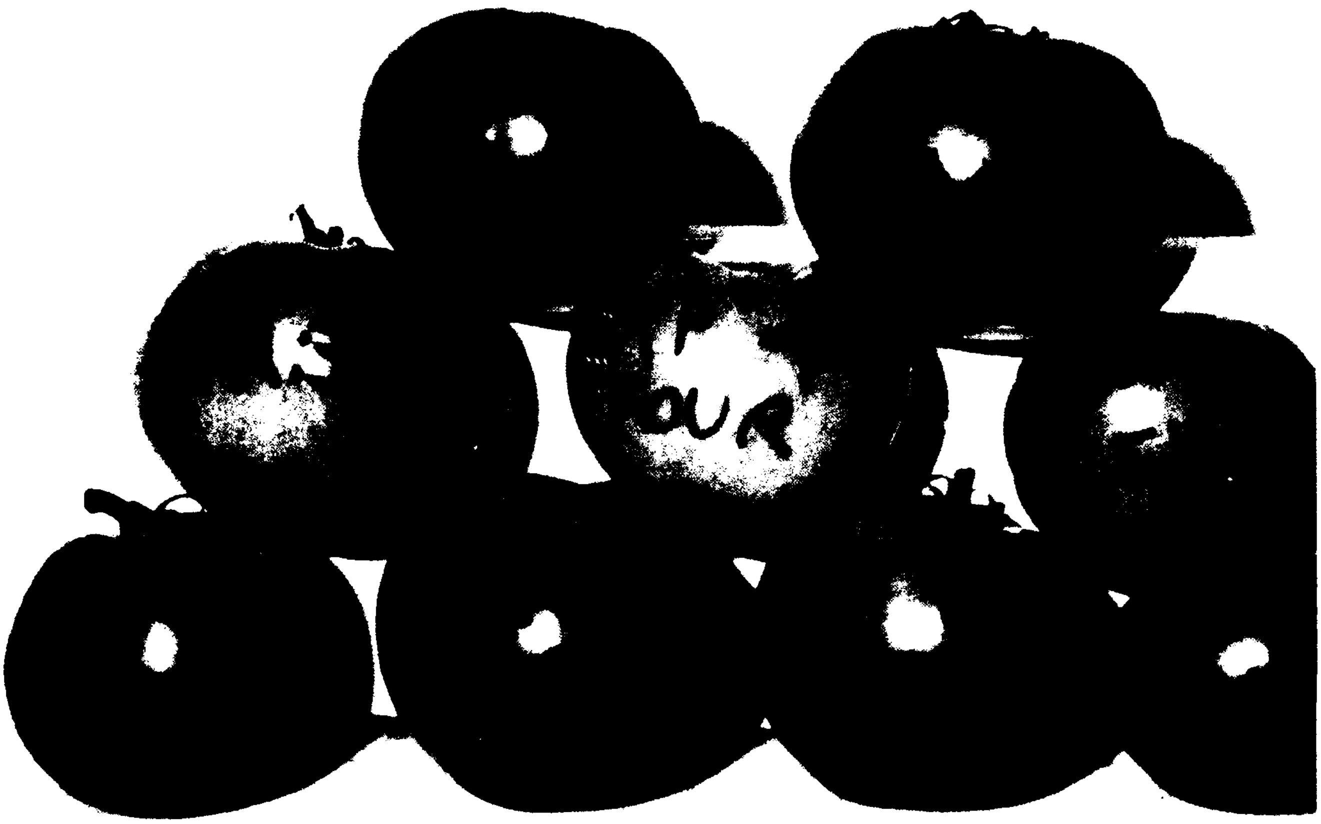


Figure 28. NASA control seed mechanical shock test; tomatoes grown from NASA control seeds after exposure to high levels of gravity

APPENDIX A

PROPOSED AIR GUN SHOCK TEST EXPERIMENT ON SEEDS

SMCAR-AEC-E 20 November 1990

MEMORANDUM FOR SMCAR-IS, Mr. Mark Eldridge

SUBJECT: Proposed Air Gun Shock Test Experiment on Seeds

1. In the quest for projects that could support the Air Gun Shock Test Facility, in anticipation of declining workloads due to the shrinking defense dollar, the "Seed Project" was conceived as a possible approach to create new business.

2. It is proposed to conduct a limited experimental test program on "Seeds" by subjecting them to increasing levels of high "G" shock environment (up to 150,000 G's) in the air gun test facility located in Bldg. 3111.

3. The object is to determine the effect of this high "G" shock environment on the genetic structure of the plant seeds and consequently its respective growth pattern. It is planned to conduct approximately 10 shots in the air gun which will be performed free of charge.

4. It is hoped that these tests could produce surprising results that could interest other Research Groups to follow through on their own test programs and thereby generating new business.

5. A recent article in the Picatinny newspaper, the voice, dated 25 Oct 1990, which caught my attention, described Mr. Roger Wentling's work on Seed Gene Pool Preservation. I contacted him and described the proposed seed project which he expressed a strong interest in. He agreed to carry out the planting process with his associated equipment and prepare a report provided he gets approval from his supervisor.

6. Therefore, it is suggested that a joint effort be undertaken on this limited test program that can be mutually beneficial. The program will be limited in the sense that this effort will stop after the seeds have germinated, the results examined, and a brief report prepared if the results are significant.

7. Enclosed are some recent articles on other seed projects that you may find interesting.

1 Encl
as

CARLO DEFRANCO
Mechanical Engineer

PLANTING IDEAS ON SCIENCE

Seeds from space offer chance to learn about heavens

By KITTA MacPHERSON

Exactly 100 tomato plants, 50 of which spent six years in space as seeds, have occupied the back left corner of Al Paganelli's high school honors biology classroom since April 12. Until last week, not one of Paganelli's 20 West Orange High School students knew which were the standard Earth variety and which had been space-borne.

Of course, some had suspicions, constantly scanning the lot for mutations.

"We were expecting a difference, since half of them had been in space for a period of time, and there was a sense that cosmic rays may have had some influence," said Britt Kramer, a ninth grader who helped Paganelli tabulate weekly growth rates.

Others were skeptical. "I didn't think there'd be any difference," said Scott Jonas, a 16-year-old member of Paganelli's class. "I couldn't believe that cosmic rays would have any influence."

National Aeronautics and Space Administration (NASA) officials were betting on such differences among students when they created one of the country's largest ever school science projects, which is coming to a conclusion.

Called the SEEDS experient, for "Space Exposed Experiment Developed for Students," the project was designed to make students interested in science and the space program.

As part of the experiment, about 12.5 million tomato seeds were lofted into space aboard an 11-ton satellite in April 1984.

The seeds were to have been retrieved after about 10 months. But the January 1986 Challenger disaster brought extensive delays to space travel, postponing retrieval of the seeds until the January 1990 flight of the Columbia space shuttle.

That extended voyage invited inquiry, since it allowed the seeds to be exposed to a mega-dose of radiation, in space terms, on March 13, 1989, when a solar flare induced one of the largest geomagnetic storms ever to sweep the Earth.

Curiosity turned to controversy in April, when it was reported NASA had failed to inform schools that the company producing the tomato seeds had sent a memo to the space agency advising them to warn schoolchildren against eating the tomatoes.

Alarmed school officials at first considered pulling the plants out of school, but re-considered when NASA officials said the chances of a mutated plant producing poisonous fruit was the same for the space seeds as for standard Earth varieties.

Nonetheless, officials at many participating schools, like the Fords Middle School in Woodbridge, told students not to eat the tomatoes as a precautionary measure.

In New Jersey, several schools are participating in the national experiment besides West Orange. They include schools in Woodbridge, Mountain Lakes, Newark and Franklin Township, Somerset County.

Although there were jokes about giant tomatoes growing in the back of their West Orange classroom, students there never regarded the plants as threatening, their fears assuaged by their teachers.

"We knew the board of education would never let us have anything dangerous in here, so we were never really afraid," Britt Kramer said.

Photo by Pim Van Hemmen

Biology teacher Al Paganelli, right, and student Scott Jonas water some of the tomato plants grown from seeds that spent six years in space

By most accounts, however, the plants took a little getting used to. In April, when the seeds began sprouting in pots, students shot curious glances to the back of the room at their leafy visitors. By May, the plants had become part of the scenery.

Last week, the tomato seedlings had achieved pet status, destined for the homes and gardens of their student-observers for the summer.

Throughout the experiment, the student's 42-year-old mentor observed the students' behavior with a sense of admiration and humor. Paganelli has taught biology at West Orange since he graduated William Paterson College with a biology degree in 1969. He said he is not so sure that the NASA experiment will convince his students to become scientists.

"A lot of these students are good at everything," said Paganelli, who teaches three other sections of biology students from the ninth and 10th grades. "I don't see it as my job to talk them into being scientists. I am supposed to help them find for themselves what they are good at and help them pursue that."

As part of that philosophy, he promises his students that with every day's lesson, he will impart a practical notion that they can use.

As a result, a biochemistry lecture will explain how specific foods cause weight loss. A lesson on the interplay between the sun and the biosphere will include a caution on how to avoid skin cancer.

Humor is also part of his equation.

During a visit to Paganelli's class last week, a visitor observed the group in the process of dissecting dead frogs so that musculature and organ systems could be identified.

"Is this the brain?" asked one student, his scalpel a little too deep in the area he was pointing to.

"That *was* the brain," Paganelli joked. "Don't be a brain surgeon."

The tomato experiment is harder to translate into practical lessons, being more of an exercise in pure science in which students are being exposed to the classical scientific method, he said.

Along with the highs of watching the seeds sprout and push through the soil were the lows of taking weekly measurements. By this month, many of the students were beginning to get bored with the routine, he said.

At that point he reminded them they were close to the end, when he would reveal whose seedlings had journeyed through space. "That seemed to give them a lift," Paganelli smiled.

The students made daily observations of the plants within the first two weeks of planting, and then took weekly measurements of the plants for the next eight weeks.

Although the rates of germination didn't vary between the two groups of tomatoes, there did appear to be a slight disparity in growth rates, with the space-borne seeds producing slightly more stunted plants, Paganelli said.

As students throughout the country complete the experiment and send the results to NASA, the space agency will conduct a statistical analysis and reveal the results later this year.

Paganelli, however, was quick to note that the experiment lacked many parameters that would insure uniformity among students at different schools.

For example, students were not told what kind of soil or fertilizer to use, so that will vary in different regions of the country, Paganelli said.

During spring break, many students across the country were allowed to take plants home, exposing them to a host of different environments. A core group of Paganelli's students, instead, came into the school over spring break to care for the plants.

Because the students received the seeds so late in the school year, there was not enough time for the plants to produce fruit, so that will have to be observed over the summer and reported back to the schools in the fall. Students have also been instructed to collect the seeds produced in the fruit for future experiments.

Scott Jonas, the skeptic, said he had enjoyed the experiment. It showed him the growing environment of Earth might be superior to a zero-gravity habitat, he said. As a result, engineers designing space vehicles for long-term space travel might have to mimic the Earth if they are to create a growing environment that is fruitful, he said.

Whether or not the data is scientifically reliable, Paganelli believes the students will carry away a different lesson. "They learned to care for and manage living organisms," he said. "That is not such a little thing."

NEW YORK POST, THURSDAY, NOVEMBER 8, 1990

Scientists 'dust' off old theory about origin of Earth life

The chemical "seeds" for life on Earth may have arrived on dust that fell from disintegrating comets, a new analysis suggests.

That would have occurred as Earth orbited through huge dust clouds that were rich in organic molecules, scientists say.

The suggestion has been made before, but the new analysis finds evidence for it in a recent discovery in Denmark.

Kevin Zahnle and David Grinspoon of the National Aeronautics and Space Administration's Ames Research Center at Moffett Field, Calif., discuss the hypothesis in today's issue of the British journal Nature.

The Danish discovery, reported last year, was that some ancient soil contained concentrations of amino acids that apparently came from outer space. Amino acids are crucial to life.

The amino acids appeared in strata above and below a layer of the element iridium, which some scientist say marks the impact of a huge meteorite that killed off the dinosaurs 65 million years ago.

The scientists who found the amino acids suggested that they had arrived on the meteorite — an idea that met with some skepticism.

Zahnle and Grinspoon suggest that the meteorite was only a chunk of a large comet, which created a dust cloud that lasted thousands of years. Dust from this cloud deposited the amino acids in the soil before and after the meteorite impact, they propose. *AP*

Did a Rain of Comets Nurture Life?

In recent years origin-of-life researchers have buzzed over a provocative notion: that comets could have supplied Earth with all the building blocks for primordial living molecules. From 30 September to 2 October, 55 specialists gathered at the University of Wisconsin at Eau Claire to discuss "Comets and the Origins and Evolution of Life," debating some intriguing proposals about how comets might have contributed to those origins—and how their signature might still be discerned.

Bringing a Comet in for Landing

PATRICIA PIERCE

A comet, so the phrase goes, is a dirty snowball, and much of that dirt is organic materials—formaldehyde, hydrogen cyanide, and more complex substances. But those materials are also fragile. What a waste it would have been, some researchers studying the origins of life say, if that organic cargo had been destroyed by the heat of impact as comets bombarded the early Earth. If those fragile compounds had somehow survived, these researchers think, they could have provided the starting point for the chemical evolution that led to more complex molecules like amino acids, nucleic acids, and, ultimately, the giant molecules of living things.

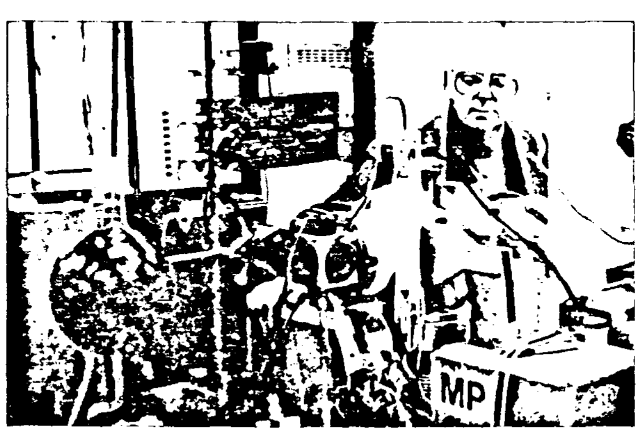
That's where astrophysicist J. Mayo Greenberg of the University of Leiden comes in. He thinks he knows how to get the organic building blocks safely to Earth. Key to that happy landing, he told his audience at the meeting, are his recent studies of the insulating properties of cometary ice, which he thinks could protect organic molecules from the heat of impact.

Not everyone agrees with the assumption implicit in Greenberg's proposal—that there's a need for an extraterrestrial source of organic compounds. At the Eau Claire meeting, chemist Stanley Miller of the University of California, San Diego, famous for the 1950s experiments in which he sparked the formation of amino acids and hydrogen cyanide in a mixture of simple precursors, defended the traditional view that the compounds were homegrown. Reactions driven by lightning and ultraviolet light in a methane- and ammonia-containing primordial atmosphere, he said, could have produced the same building block compounds found in comets. But under different assumptions about the composition of the ancient atmosphere, Carl Sagan of Cornell University points out, "endogenous synthesis would be difficult, and you would have to import organics."

As Sagan and his colleagues Christopher Chyba and Paul Thomas of Cornell and Leigh Brookshaw of Yale University showed in a paper last year in *Science* (27 July 1990, p. 366), that's no mean feat. According to their computer simulation, only small parts of a comet plowing into the atmosphere would stay cool enough to preserve organic chemicals. The group did hold out the hope that if small fragments broke off the comet and wafted gently to Earth, the organic materials they harbored might survive. But Greenberg told the conference that he now has reason to think much more of the cometary cargo could survive the collision.

He bases his proposal on laboratory simulations of the icy particles that make up comets. To create them he condenses mixtures of water vapor, methane, carbon monoxide, and other gases present in interstellar space onto a glass plate cooled to 10°K. Earlier experiments had shown that the ice deposited at these low temperatures is amorphous, having a disorderly molecular structure rather than the usual crystalline one.

Amorphous ice conducts heat more slowly than crystalline ice. Now Greenberg has found that when the ice is deposited very slowly, as it would be on interstellar grains, its thermal conductivity is lower still, by a factor of 10,000 to 100,000. The reason, he speculates, may be the "lesser connectedness" of water molecules that have accumulated slowly. And the effect of this extraordinarily low thermal conductivity might have been to insulate organic materials against the heat of a cometary impact. While the outer layers of the grains were vaporized during the comet's collision with the atmosphere, the inner parts might survive unscathed and float gently to Earth.


JOSEPH MARCUS

The ice man. *Mayo Greenberg in his laboratory at Leiden.*

Chyba is skeptical. "You must still remove from the comet the millions of megatons of TNT worth of heating that would occur with a large impactor"—enough to destroy organic material throughout the comet. "It just seems too hopeful." Still, says Thomas, he and Chyba would be interested in seeing a computer model of a comet impact incorporating Greenberg's notion, to see if it gives a more hopeful prognosis for the survival of cometary organics.

The discovery also has a practical implication, Greenberg points out. In 2002, the European Space Agency plans to launch its Rosetta mission to drill a 3-meter core sample from a comet and return it to Earth. Thanks to the powerful insulating properties of cometary ice, Greenberg says, drilling so deep may not be necessary. "Even periodic comets heated by the sun preserve pristine interstellar matter in cold storage at relatively shallow depths" of just tens of centimeters, he estimates. But the deep cold just under the comet's skin also means, he says, that getting the comet stuff back to Earth in its native state may require "a greater effort to provide the lowest possible return temperature—preferably less than 20°K"—to match the cometary deep freeze.

A Cometary Source for Cockeyed Molecules?

Stanford University chemist William Bonner has a special reason to root for J. Mayo Greenberg. If comet stuff could have landed intact on the early Earth, he explained to meeting attendees, he and his fellow chemists who have been puzzling over molecular handedness could get on with their lives.

One of the most mysterious features of present-day biomolecules is the fact that the ribose and deoxyribose sugars in DNA and

APPENDIX B

EFFECTS OF GRAVITY FORCE ON TOMATO SEED CHARACTERISTICS GERMINATION, GROWTH, YIELD, AND QUALITY

Alexandra R. Chutoransky
Peter Chutoransky, Jr.

October 4, 1991

SUMMARY

Tomato seeds subjected to ultra-high gravity forces between 1.3 and 119.4 thousand Gs were studied from seed germination through produce yield and quality evaluation. Seeds were germinated in and plants grown in both potting soil and lava rock. One batch of seeds was seaweed pre-soaked. NASA seeds which had been exposed to zero gravity were included in the germination portion of the study. Controls were used in all evaluations. All seeds were supplied by Roger Wentling and Carl DeFranco of Picatinny Arsenal.

Differences related to G-force exposure were observed. The most pronounced was the tomato produce quality at higher G-force. At high Gs tomatoes were superior in overall quality, had smaller amounts of seed liquid mass, thicker and more solid pulp walls and very good to superior taste and texture. All were generally poorer for the control and at lower G-forces.

Abnormal off-plant green tomato ripening was also observed for seeds subjected to G-forces between 4.2 and 30.7 thousand. Rather than ripening in a sunny window, they aged as solid brown discolored tomatoes and then became wrinkled like prunes. The non-ripened portion remained solid green tomato.

While the abnormal tomato ripening should be of research interest, the improved quality characteristics of the high-G tomatoes could be of some commercial significance. Each deserves more extensive and quantitative investigation.

RESULTS

Germination - Seeds Subjected to Ultra-High Gravity Forces

With the primary batch of seaweed-soaked seeds, germination time varied between 13 and 33 days. With the lava rock medium most of the earlier germination times were observed; additionally, germination yields were 60 % higher.

	Germination Times		
	10-17 days	32-33 days	# Germinated
Soil	1 (25%)	9 (75%)	10
Lava Rock	3 (75%)	3 (25%)	6
Total	4	12	16

	Germination Yields		
	Germinated	Planted	Yield
Soil	10	24	42 %
Lava Rock	6	9	67 %
Overall	16	33	46 %

All early germination seedlings were long, leggy and weak due to lengthy exposure to damp dark extended germination period. None were able to tolerate bright sunlight and all died within 2 to 7 days in the greenhouse.

Initial real leaves were observed on all seedlings between 36 and 38 days.

Plants in lava rock grew much more slowly than those in potting soil, requiring daily watering with weak fertilizer solution to keep plant roots moist and to prevent total dehydration.

Plant Height (inches)

	Day 61	Day 99	Day 145
Soil	8 - 11	14 - 26	20 - 25
Lava Rock	2 - 4	3 - 5	15 - 18

Germination - Seeds Exposed to Zero-Gravity in Space (NASA)

Germination times with NASA seeds similarly seaweed pre-soaked, but at higher temperatures, were between 12 and 20 days. These seeds were all germinated in seed started soil, none in lava rock. Overall yield was comparable at 50 percent with two-thirds maturing to full plants.

Germination Times

	12 days	15 days	20 days	Total
Soil	2 (33%)	3 (50%)	1 (17%)	6

Germination Yield

	Germinated	Planted	Yield
Soil	6	12	50 %

Germination - Seaweed Soak Solution Concentration Analysis

The effect of seaweed soak solution concentration was determined with control seed and at the same temperature as the NASA seeds. Again all seeds were germinated in seed starter soil, none in lava rock.

Germination times for the control seeds under these conditions were shorter and germination yields higher than with either the earlier test batch or the NASA seeds. Additionally, germination times and yields were independent of concentration which was varied from .002 to 4.0 tablespoons per gallon of 50/50 MaxiCrop/Enzoom seaweed powder and hormone, respectively. A pure water control was used. Both the earlier batch and the NASA seeds were pre-soaked at 1.0 tablespoons per gallon concentration.

Overall gemination yield was 87%.

	Gemination Times (Control Seeds) 13-15 days	20 days	50 days	# Geminated
Seeds Geminated (4-5 seeds sets)	45 (94%)	2 (4%)	1 (2%)	48

The percentage of seedlings growing into mature plants was 3 times better when pre-soak concentrations were higher.

(Maxicrop/Enzoom Tbls/gal)	Maturing to Full Size Plants (Control Seeds) Water & .002 - .125	.25 - 4.0
Grew to Mature Plants	9	18
Seeds Geminated	33	22
(% to Mature Plants)	(27%)	(82%)

Initial Flowering & Fruit Production

All plants were container grown (12 inch cylindrical plastic pots with peat moss based professional quality potting soil or lava rock). As mature plants they became root growth constrained and frequently experienced very dry soil conditions even though watered daily. Lava rock plants needed to be watered once or twice daily, but to-date are not large enough to be root-growth constrained.

Initiation of flowering and initial fruit formation occurred between days 95 and 100 for all seaweed pre-soaked specimens in soil. Both flowers and fruit were well formed, standard in appearance and grew normally for all plants, independent of ultra-high gravity treatment.

The observed variability in plant quality, foliage die-back, initial production of vine-ripened red tomatoes, etc could not be directly related to ultra-high gravity force treatment.

Abnormal Off-plant Fruit Ripening

Tomatoes subjected to gravity forces between 4.2 and 30.7 thousand Gs were observed to ripen abnormally as green tomatoes. These tomatoes fell off the plants into soft grass when the potted plants were blown over by a strong wind with no visible damage. These green tomatoes were placed on a sunny window to ripen.

Rather than ripening to deep red tomatoes, they developed a deep dark brown discoloration from within, similar to a "black and blue" on your body. The area of discoloration never softened or decayed, but remained firm even when half the tomato progressed to this state. The result of further ripening/aging produced tomatoes that looked like prune s with badly wrinkled surfaces over most of the tomato. These areas were dried-out , not rotten or soft. The remaining green tomato portion was still firm and soil, just as it was when placed in the sunny window to ripen.

Plant Growth and Tomato Fruit Yield & Quality

When substantial tomato production occurred (25-50 or more tomatoes per plant), severe die-back was observed with most plants; stalks were generally broad and strong. When tomatoes were fully vine-ripened red, many plants had essentially no foliage left. A few generated new well-formed green shoots after 100 days, growing nicely over the following 20-30 days to-date.
While variability occurred, some definite trends were observed.

o Overall production of vine-ripened red tomatoes from plants in the ultra-high gravity force range 58.4 - 98.3 thousand Gs was about 2.5 times that of the other plants, 1700 versus 700 grams per plant (Roger Wentling non seaweed pre-soaked)

- While overall yield appeared G-independent, the control plant just started to yield minimal quantities of red tomato produce 3 weeks after most other plants. (Seaweed pres-soaked plants)

o Produce quality, taste and texture generally improved with increasing G-force.

- Overall, tomatoes were fair-to-good for control and low-G; very good-to-super at high-G.

- Large amounts of seed-fluid mass for control and low-G; smaller amount (about half as much) at high-G.

- Solid pulp walls numerous and thinner for control and low-G; much thicker and most of tomato at high-G.

- Taste, texture and deep red color fair-to-good for control and low-G; very good-to-super at high-G.

Note: Superior quality, taste and texture were obtained with the seaweed pre-soaked samples. While Roger Wentling's non seaweed pre-soaked were poorer, similar trends were observed.

Tomato Seeds for Follow-up Studies

Seeds were collected for second generation genetic permutation studies from all plants, both seaweed pre-soaked and not.

PROCEDURES

Seaweed Pre-Soak

A solution of Maxicop soluble seaweed power and Enzoom seaweed hormone liquid was prepared by mixing 1/2 tablespoon of each in a gallon of water.

Each batch of 2-3 seeds was placed in about 50cc of solution in a glass cup and covered with clear plastic wrap. They were allowed to stand at room temperature in a dark dry environment for 3 days.

Planting Seeds

A plastic tray with 2"x2"x2" cubes was filled with Hoffman's Seed Starter natural soil (peat moss based), soaked with water and the 2 seeds from each treatment & the control were placed about 1/4-1/2 inch below the soil surface.

One seed from 6 treatments and the control were also planted in crushed lava rock about 1/8-1/2 in size (original lava rock was 1/2 - 2 1/2 inches).

The trays were covered with plastic sheet, kept at room temperature and placed where they would receive very little light . When most of the seedlings had germinated the plastic sheets was removed and the seedlings moved to the greenhouse.

Note: With the initial germination batch, most of the seeds had not germinated after 18 days and the tray was moved into the greenhouse which was bright with sunlight and often went up over 90 degree during the day. Gemination of most seeds occurred about 2 weeks later.

Seedling Growth under Lights

The trays of seedlings were placed under fluorescent light (6 40-watt soft and cool white lamps) with the lamps only 1-2 inches above the top leaf surface. Light was maintained 16-18 hours daily.

Note: The lava rock plants were still very small and were kept under lights till about 6" high.

Transplanting into Large Pots

When approximately 10 inches high and very strong, the plants were moved to 12" diameter x 12" high plastic pots with with the roots as low as possible in the pot, often with 1-2" of the bottom. Professional quality peat moss-based potting soil (Fisons Sunshine Mix #2) was pre-soaked and used for all samples germinated in soil.

The lava rock samples were placed similarly in 10" diameter x 10" high plastic pots with 1/4-3/4" lava rock as the growing medium.

Note: The following items were added to the soil or lava rock for each plant when transplanted :
1 Tablespoon Tomatoes Alive
1 Tablespoon Garden Limestone

Plant Fertilization

Plants in soil were watered daily or when dry and fertilized with Miracle Gro for Tomatoes weekly at the rate of 1 tablespoon per gallon per plant weekly. The lava rock was fertilized daily with a solution about half this concentration.

Gathering Produce

Tomatoes were picked only when fully vine-ripened red. They were weighed and judged for quality.

Tomato Seed Collection

Fluid seed mass (50-100+ seeds) were extracted and rolled in adsorbent paper towels to dry and store over the winter for further studies next Spring.,

Qualitative observations were made about tomato quality, as well as variations in solid pulp, amount of fluid seeds mass and taste, texture and color of solid tomato pulp.

Note: Exact measurements were not made, since the significant of variations with G-force was not realized until later analysis.

Table 1

TOMATO GROWTH DETAILED DATA - SEAWEED PRE SOAKED

Run - Sample	Gravity Force Gs (000)	Germ Time Height Comments	24-Jul Day 99	5-Aug Day 111	9-Sep Day 145 Tomato & Plant Notes	Produce Yield (Exterior Quality)	Produce Quality (Cut Tomato)
C - 2 Soil Pot 13	0	32 days 9 1/2" Great	Buds 20"	Few Buds Some Die Back	No Red Tomatoes Yet Some Die Back Leathery Green Leaves	x x x	<18 Sept Day 155> Fairly Meaty - Lots Lots Seed Liquid (most) Red Fair Taste & Texture
1 - 1 Soil Pot 8	1.3	32 days 10" Great	Flowers 19"	Few Tomatoes Lots of Buds	3 Nice Red Tomatoes Most Foliage Gone New Green - Very Dry	185 grams (45 - 90 gms) Very Nice Red Solid	Meaty - Lots Seed Liquid Deep Red Very Good Taste & Texture
1 - 2 Soil Pot 22	1.3	32 days 10 1/2" Great	Buds 25"	Few Tomatoes Lost of Buds	5 Nice Red - Cluster 2 Small Fair Red Most Foliage Gone Little New Green - Very Dry	575 Grams (40 - 150 gms) Very Nice Red - Solid Fair Poor - Soft	Meaty - Medium Seed Liquid Deep Dark Red Very Good Taste & Texture
4 - 2 Soil Pot 52	19.5	32 Days 9 1/2" Very Good	Flowers 14"	Lots of Buds	2 Fair Red Tomatoes Very Little Foliage New Green - Very Dry	150 grams (50 - 100 gms) Very Nice Red Firm	Meaty - Lots Seed Liquid Deep Dark Red Very Good Taste & Texture
6 - 2 Soil	52.3	32 days 10" Great	Flowers 20"	Few Tomatoes Buds	4 Very Nice Red Tomatoes 1 Fair Red Very Little Foliage 1 Big Green Shoot - Dry	410 grams (80 - 125 gms) Very Nice - Light red Fair Poor	Meaty - Lots of Seed Liquid Deep Dark Red - Firm Good Taste & Texture (Fairly flat)
8 - 1 Soil Pot 39	38.6	32 days 8" Great	Buds 16" Some Dried Up Foliage	Few Buds	No Red Tomatoes Yet Lots of Green Best Plant Good Green	<30 Sept Day 177> 200 grams (2 @ 100 gms) Very Nice Red	<30 Sept Day 177> Meaty - Medium Seed Mix Deep Dark Red Very Good Taste & Texture
9 - 1 Soil Pot 16	98	32 days 9 1/2" Great	Flowers 23"	Lots of Tomatoes Great - Little Die Back	2 Very Nice Red 3 - 4 Medium Red Most Foliage Gone No New Green	260 grams (110 - 170 gms) Very Nice Red	Meaty - Not Much Seed Liquid Deep Dark Red Super Taste & Texture
9 - 2 Soil Pot 2	98	32 days 11" Great	Buds 23"	Few Tomatoes Few Buds Nice - Little Die Back	2 Very Nice Red Most Foliage Gone 2 New Green Shoots - Dry	240 grams (110 - 140 gms) Good - Light Red Solid	Meaty - Quite a Bit Seed Liquid Deep Dark Red Very Good Taste & Texture
10 - 1 Soil Pot 11	98.3	32 days 11" Super - BEST Roots thru Pot	Buds 26"	Some Tomatoes Lots of Buds Great - Little Die Back	4 Very Nice Good Size Red Most Foliage Gone 4 5 Nice New Green Shoots	610 grams (90 - 140 gms) Very Nice Red Good - Red Orange	Very Meaty - Little seed Liquid (Least) Deep Dark Red Super Taste & Texture
3 - 2 Lava Rock		32 days 3 1/2" Small Well Formed	4" Small Roots	x x x	2 Green Tomatoes Lots of Flowers Very Nice Plant	x x x	x x x
8 - 3 Lava Rock		32 days 4" Small Well Formed	5" Beautiful Root Ball	x x x	6 Small Green Tomatoes Cluster Nice Plant Minor Die Back	x x x	x x x

Table 2

TOMATO GROWTH DETAILED DATA NON SEAWEED PRE SOAKED (Roger Wenting Seedlings)

Run - Sample	Gravity Force Gs (000)	16-Jul Height	6-Aug Yield Plant Quality	29-Aug Initial Yield	8-Sep Total Tomato Yield	8-Sep Produce Exterior Quality	8-Sep Produce Quality (Cut Tomato)
C (XP13) Soil Pot 3	0	17"	Tons of Tomatoes Little Die Back	5 Red Tomatoes 575 grams	900 grams	Fair	Meaty - Lots Lots Seed Liquid (most) Deep Red Good Taste & Texture
1 / 3 Soil Pot 42	1.3	17"	Lots of Tomatoes Some Die-Back	5 Red Tomatoes 690 grams	900 grams	Good Brownish Discoloration	Meaty - Lots Lots Seed Liquid Deep Red Very Good Taste & Texture
2 / 3 Soil Pot 4	4.2	19"	Tons of Tomatoes Some Die Back	4 Red tomatoes 470 grams	470 grams	x x x	Meaty - Lots of Seed Liquid x x x Fair Taste & Texture
4 / 4 Soil Pot 51	19.5	14"	Tons of Tomatoes Some Die-Back	4 Red Tomatoes 610 grams	1100 grams	Fair	Meaty - Medium Seed Liquid x x x Good Taste & Texture
5 / 2 Soil Pot 19	30.7	16"	Tons of Tomatoes Some Die-Back	2 red Tomatoes 280 grams Almost Dead Plant	280 grams	Very Nice	Meaty - Medium Seed Liquid x x x Poor Taste & Texture
6 / 2 Soil Pot 23	52.3	23"	Tons of Tomatoes Some Die-Back	5 Red Tomatoes 500 grams	500 grams	x x x	Meaty - Lots of Seeds x x x Fair Taste & Texture
7 / 3 Soil Pot 27	58.4	19"	Tons of Tomatoes No Die Back	3 red Tomatoes 380 grams	1500 grams	Very Nice Solid	Meaty - Lots of Seed Liquid Deep [illegible]d Super Taste & Texture
8 Soil Pot 11	38.6	11"	Lots of Tomatoes Some Die Back	4 red Tomatoes 330 grams	420 grams	Fair/Goog	Meaty - Lots of Bit Seed Liquid Deep Red Good Taste & Texture
9 Soil Pot 8/21	98	5"	Tons of Tomatoes Minor Die-Back	3 Red Tomatoes 630 grams	1300 grams	Very Nice	Meaty - Lots of Seed Liquid x x x Good, not Super Taste & Texture
10 / 4 Soil Pot 41	98.3	9"	Tons of Tomatoes Little Die-Back	9 Red Tomatoes 615 grams	2400 grams	Very Nice Firm	Meaty - Lots of Seeds Deep Red Very Good Taste & Texture
11 Soil Pot 20/3	119.4	18"	Tons of Tomatoes Some Die-Back	5 Red Tomatoes 670 grams	700 grams	Very Nice x x x	Lots/Lots of Seed Liquid Deep Red Fair Taste & Texture

Table 3

TOMATO SEED GERMINATION - SEAWEED PRE-SOAKED

Run - Sample	Gravity Force Gs (000)	Soil 1	Soil 2	Lava Rock 3
Control	0	x	32 days	x
1	1.3	32 days	32 days	none planted
2	4.2	x	x	10 days
3	11.4	x	x	32 days
4	19.5	x	32 days	33 days
5	30.7	x	x	x
6	52.3	x	32 days	x
7	58.4	x	x	none planted
8	38.5	32 days	x	32 days
9	98	32 days	32 days	17 days
10	98.3	32 days	x	none planted
11	119.4	13 days	x	14 days

FIG. 1 SEEDS BEING SEAWEED PRE-SOAKED.

FIG. 2 PLASTIC CUBE TRAY CONTAINING SEED STARTER SOIL AND LAVA ROCK - RUN 2 SEEDS.

FIG. 3 YOUNG SEEDLINGS EMERGING FROM SEED STARTER SOIL AND LAVA ROCK - RUN 11 SEEDS.

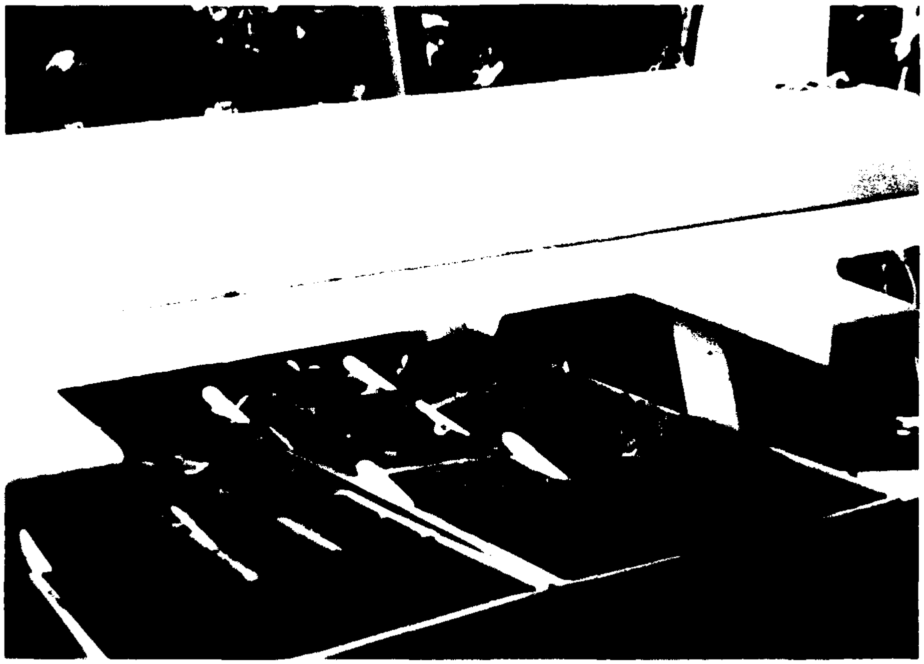


FIG. 4 TRAY OF YOUNG SEEDLING UNDER COOL WHITE AND SOFT FLUORESCENT LIGHTS.

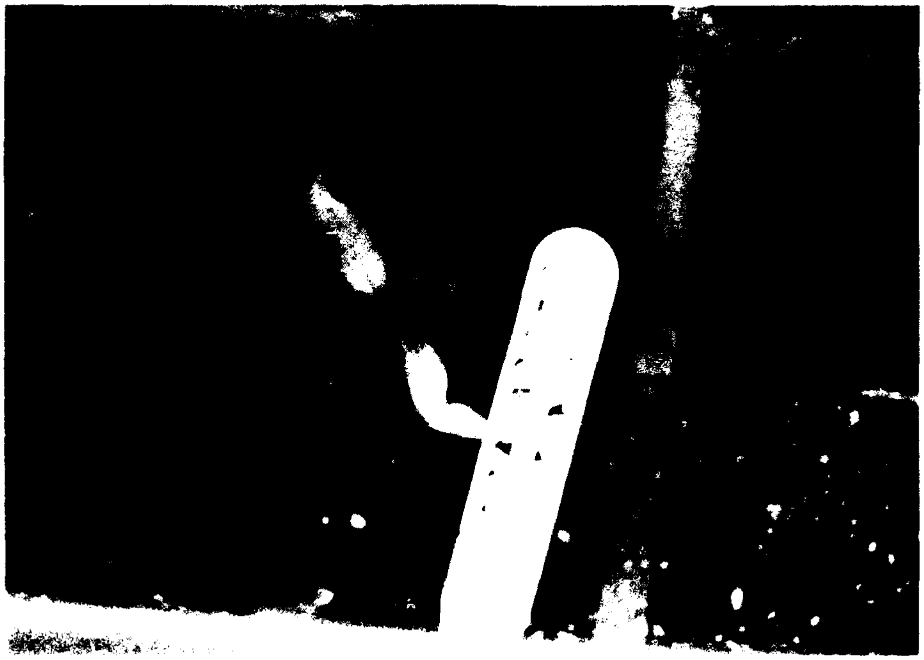


FIG. 5 YOUNG SEEDLINGS IN STARTER SOIL WITH INITIAL REAL LEAVES - RUN 10.

FIG. 6 TRAY OF YOUNG SEEDLINGS WHICH GERMINATED AT 32-33 DAYS. NOTE SMALLER SIZE AND SLOWER GROWTH OF SEEDLINGS IN LAVA ROCK

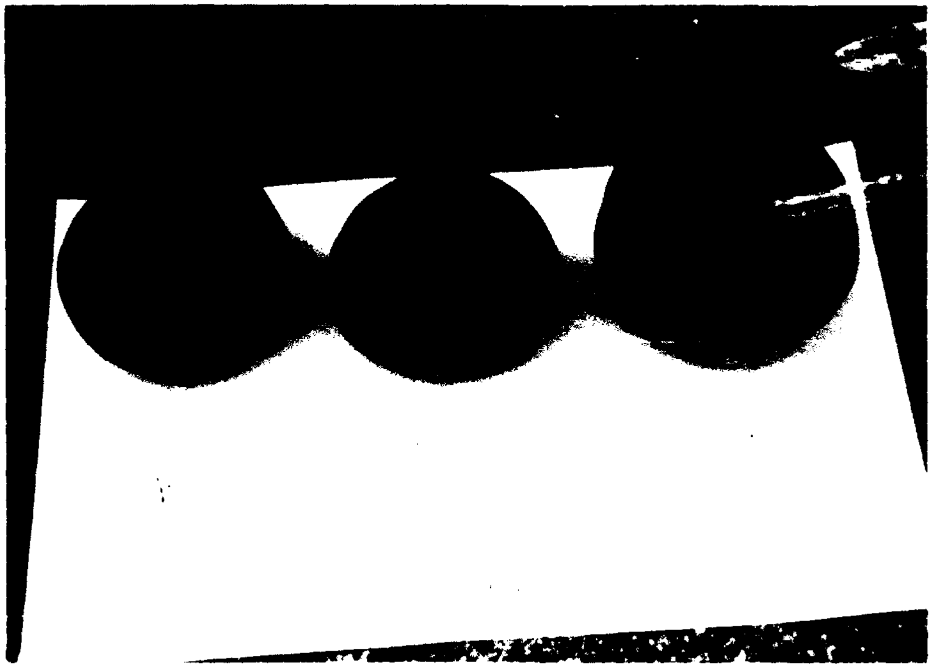


FIG. 7 ABNORMALLY RIPENED GREEN TOMATOES SUBJECTED TO GRAVITY FORCES BETWEEN 4.2 AND 30.7 THOUSAND Gs. NOTE BROWN DISCOLORATION AND FIRM STRUCTURE OF ENTIRE TOMATO, BOTH BROWN AND GREEN PORTIONS.

FIG. 8 CLOSE UP OF 'DECAYED' TOMATO - RUN 5.

FIG. 9 TOMATO PLANTS GROWING IN LAVA ROCK - RUN 3 & 8.

NOTE: ALL SINGLE PLANT PHOTOS BELOW HAVE BEEN SUBJECTED TO ULTRA - HIGH GRAVITY FORCE AND ARE TYPICAL OF MOST NON - SEAWEED SOAKED PLANTS FROM ROGER WENTLING.

FIG. 10 INITIAL WELL FORMED TOMATOES AND FLOWER IN CLUSTER.

FIG. 11 TOMATO PLANT WITH MINIMAL DIE - BACK.

FIG. 12 GROUP OF TOMATO PLANTS UNDER TEST, MOST SHOWING SOME DIE - BACK.

FIG. 13 CLUSTER OF GREEN TOMATOES WITH PLANTS SHOWING SOME DIE - BACK AND DRIED - UP LEAVES.

FIG. 14 MATURE PLANT WITH LARGE CLUSTER OF TOMATOES AND MOST FOLIAGE GONE.

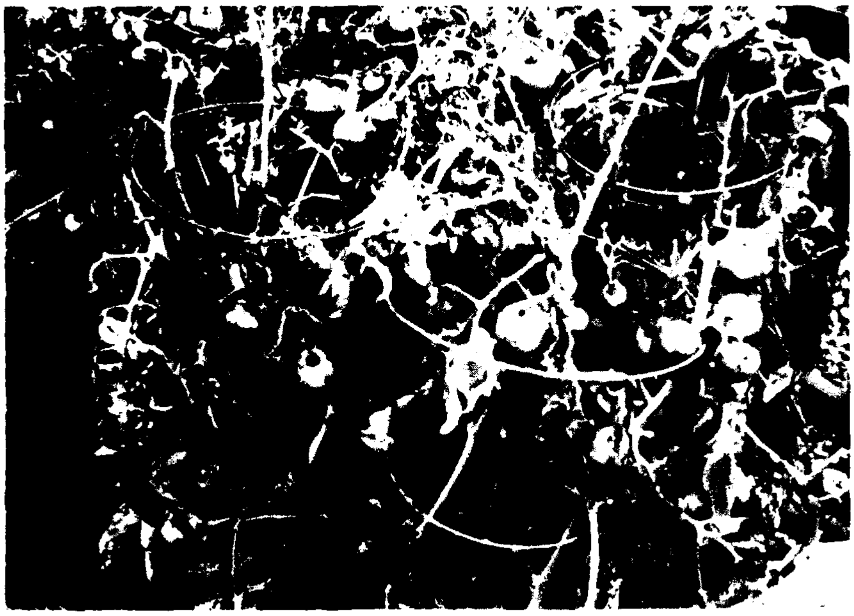


FIG. 15 NUMEROUS TOMATO PLANTS WITH MANY RED VINE - RIPENED TOMATOES SHOWING SUBSTANTIAL DIE - BACK AND DRIED UP LEAVES.

APPENDIX C

AIR GUN TEST FACILITY AT PICATINNY ARSENAL

(Article presented in Technology Review, Vol 1, No. 6, June 1991)

AIR GUN TEST FACILITY AT PICATINNY ARSENAL

by Ken Stewart

Mr. Stewart is Chief of the Environmental Test Branch at the U.S. Army Armament Research, Development and Engineering Center (ARDEC) at Picatinny Arsenal, NJ, and is a member of the SAVIAC Technical Advisory Group.

The Environmental Test Section of the Army Armament Research, Development and Engineering Center (ARDEC) provides a unique test facility for project groups at Picatinny as well as other Government agencies and contractor activities. Among its facilities are three air guns which are used to support interior ballistics and other high g simulation test requirements for items such as fuses, rocket propellants and electronic devices.

The three gas guns include a 5-inch gun, a 2-inch gun (Figure 1) and a rifled 155-mm gun (Figure 3). All three guns operate by accelerating a light-weight piston through the gun barrel by means of compressed air (or gas). The piston is stopped by the compression of air ahead of it in the barrel allowing for soft recovery of the test item.

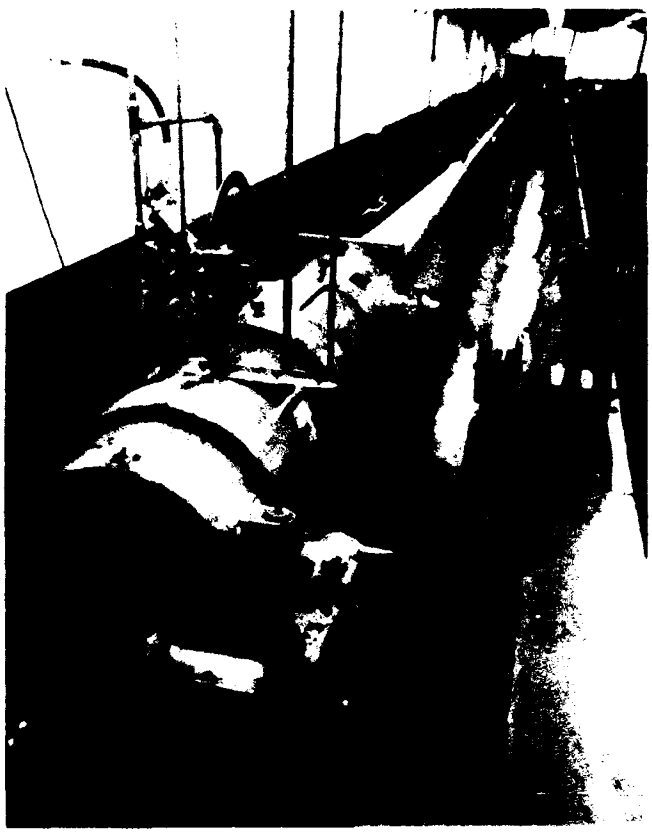


Figure 1 Five-inch (left) and two-inch guns viewed from breech end

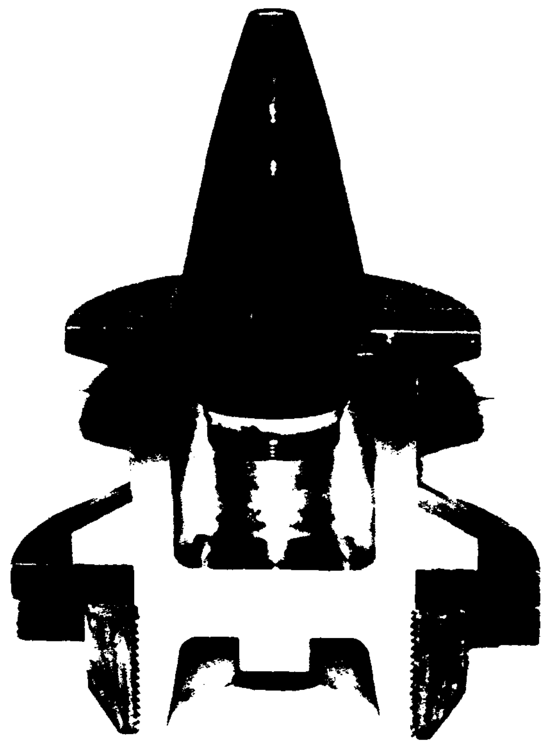


Figure 2 Test item mounted in piston with grooved diaphragm (cross sectional view) for five-inch gun

The 5 inch gun is a Navy 5 inch/51 caliber deck gun of World War I vintage, supplied by the Naval Ordnance Laboratory (now the Naval Surface Warfare Center/White Oak). The gun is smooth bored and fitted with barrel extensions to provide a total barrel length of 80 feet. The extensions are supported on rollers to allow free recoil movement. The 5 inch gun can accept test items up to 4 3/8 inches in diameter and can provide a maximum acceleration of up to 50,000 g. The test item is mounted in a piston as shown in Figure 2. Attached to the base of the piston is an aluminum, grooved

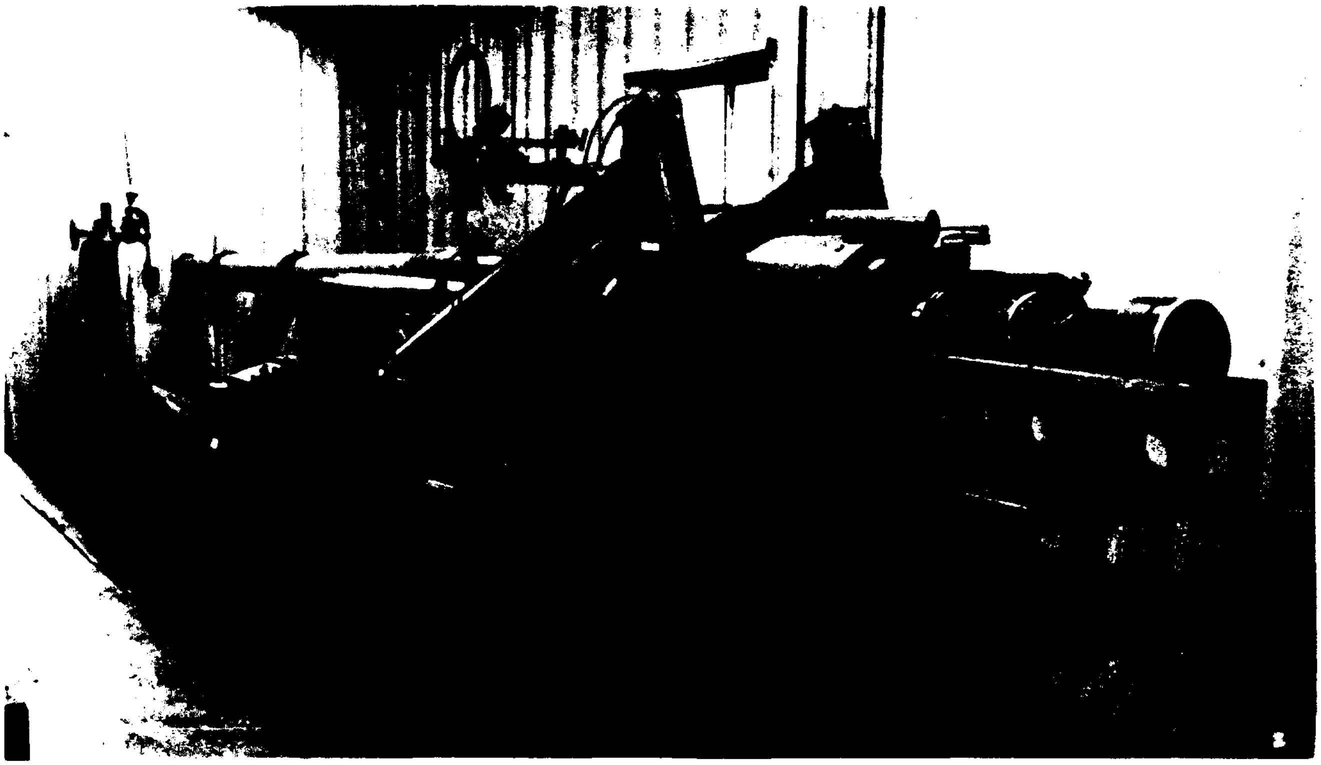


Figure 3 Breech-end view of 155 mm gun

diaphragm which ruptures at a designated air pressure. This sudden release of compressed air propels the piston forward.

The 2 inch gun has a smooth bore, is 65 feet long and can provide an acceleration of up to 200,000 g. Test items up to 1 1/2 inches in diameter can be accepted. The 2 inch gun operates in the same manner as the 5 inch gun.

The 5 inch and 2 inch air guns utilize a "diaphragm" method of firing. A comparison of the

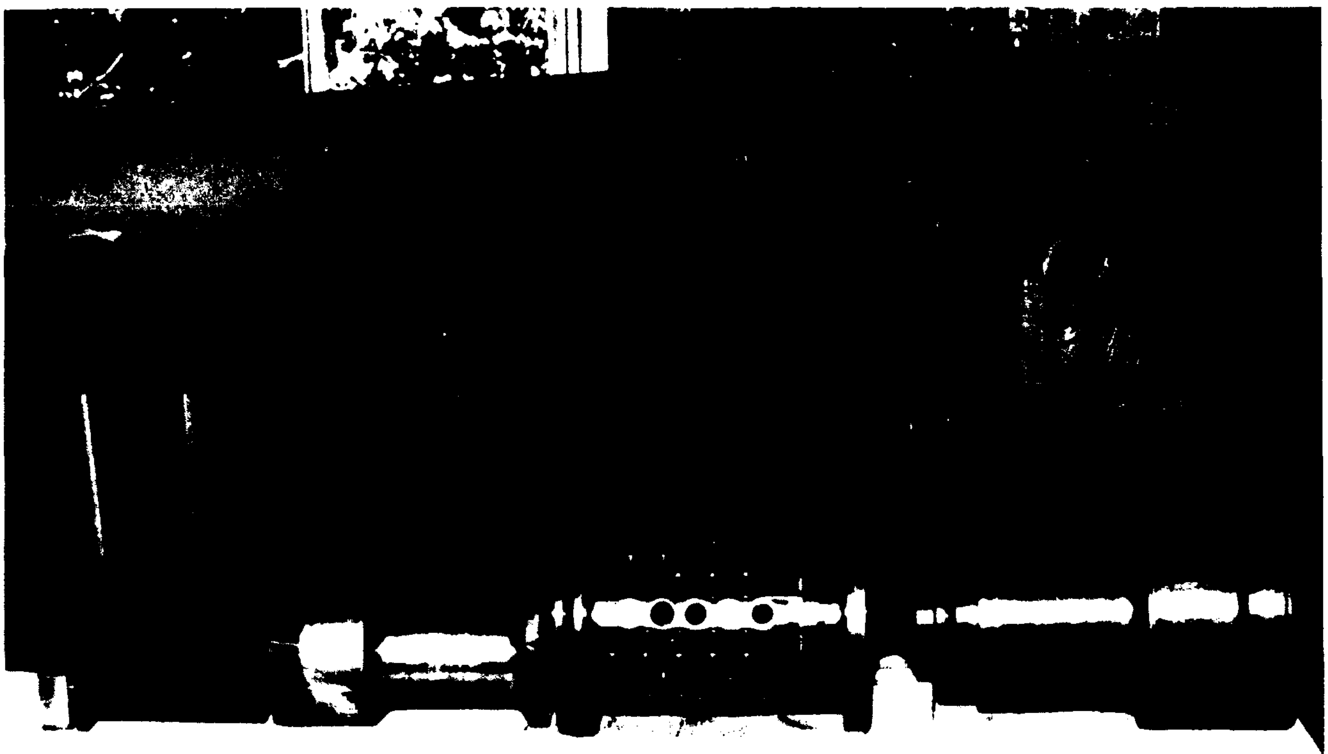


Figure 4 Shown before the 155 mm gun are, from left to right, the telemetry package, spin piston, metering sleeve and chamber block

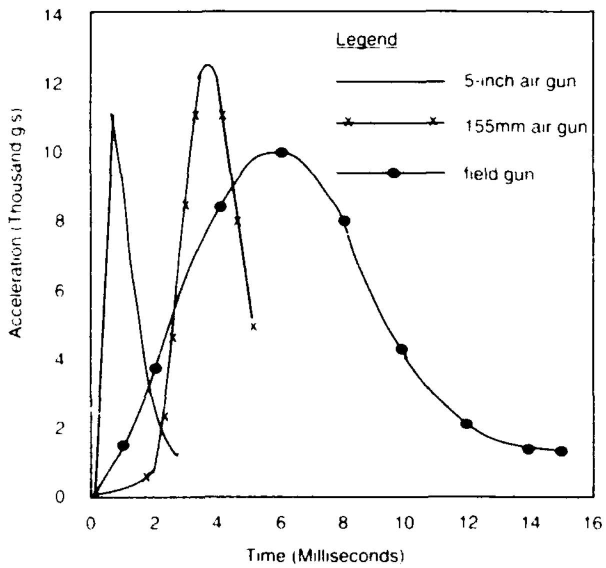


Figure 5 Comparison of acceleration pulse among the 5-inch and 155 mm air guns and an actual field gun

characteristics of field gun firing acceleration and the simulation provided by the diaphragm method in the air guns indicated that there was much to be desired. The rise time to peak acceleration in the air gun is much faster than in the field gun, and there is no significant dwell time around the maximum level. The acceleration decays much faster in the air gun, and as a result, the maximum velocities are substantially lower. In addition, using the diaphragm method does not permit control over the shape of the acceleration pulse when trying to simulate the conditions produced by various guns. To overcome these difficulties, the 155-mm gun was designed to provide a more controllable air pulse.

The 155-mm gun, based on a 155-mm field howitzer gun assembly, differs in two ways from the 5-inch and 2-inch guns. First, it is rifled, instead of smooth bored. This provides additional realism to the test. The 155 mm gun is fitted with a smooth bore barrel extension to give it a total length of 144 feet. Second, the high pressure air is introduced behind the piston in a controllable manner through adjustable metering sleeve ports (Figure 4). This permits tailoring the rise portion of the acceleration curve to more closely simulate actual gun firing. Figure 5 shows the difference achievable in the acceleration pulse between the 2- and 5-inch guns and the 155-mm gun.

An additional improvement provided for the 155-mm gun is the digital memory module. The existing methods of acquiring test data were not adequate to completely describe the acceleration and spin of the piston. A new capability utilizing an on-board digital memory module, developed by ARDEC's Telemetry Section, permits complete characterization of the ballistic launch environment. The module is completely self-contained, with its own power supply, signal conditioning electronics, analog-to-digital converters, internal clock, digital memory, and analog or digital readout after recovery. The module can record two channels of information at the same time, such as acceleration, spin, test item function events, or voltage, and can operate in environments up to 20,000 g.

Table 1 provides a summary of the air gun's performance characteristics. Additional information may be obtained from the author.

Table 1

Facility	Peak Amplitude	Nominal Rise Time	Approximate Decay Time
5-inch gun	50,000 g	0.25 msec	0.8 msec
2-inch gun	200,000 g	0.25 msec	0.8 msec
155-mm gun	20,000 g	2 to 4 msec*	1 to 10 msec

* Rise Time can be varied.

• The range (acceleration amplitude and duration) of the 155mm gas gun ballistic simulator is as follows:

Acceleration Parameters	Range
Rise time	2 to 4 msec
Duration	Approx. 5 to 45 msec
Amplitude	To 20,000 g's (at 20 lb)*
Spin rate	To 86 rps

* The attainable g varies inversely with weight. With a 10% reduction in weight, the attainable g increase is 10%. The maximum attainable g is less at the longer durations.

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